RENÉ THOM

SEMIO PHYSICS: A SKETCH

Aristotelian Physics and Catastrophe Theory

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ADDISON-WESLEY PUBLISHING COMPANY, INC.
THE ADVANCED BOOK PROGRAM
Redwood City, California • Menlo Park, California
Reading, Massachusetts • New York • Amsterdam • Don Mills, Ontario
Sydney • Bonn • Madrid • Singapore • Tokyo • San Juan
Wokingham, United Kingdom

Publisher: *Allan M. Wylde*
Production Manager: *Jan Benes*
Composition: *K. Shafer, Associates* and *Ocean View Technical Publications*
Promotions Manager: *Laura Likely*
Cover Illustration: *Patrick O'Heguerty*
Translation: *Vendla Meyer*

Library of Congress Cataloging-in-Publication Data

Thom, René, 1923–
[Esquisse d'une sémiophysique. English]
Semio physics : a sketch / René Thom ; [translated from the French by Vendla Meyer].
p. cm.
Translation of: Esquisse d'une sémiophysique
Bibliography: p.
Includes index.
ISBN 0-201-50060-4
1. Physics—Philosophy. 2. Catastrophes (Mathematics) 3. Aristotle. I. Title.
QC6. T52513 1989
501—dc19 89-30695
CIP

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Originally published by InterEditions, Paris, 1988

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ABCDEFGHIJ-MA-89

"Αλλην ἀρχὴν ἀρξόμενοι. . .
Now let us make a fresh start. . .
Aristotle, *Physica* I(9), 192b, 6

In this volume, the book *Stabilité Structurelle et Morphogénèse* (by René Thom, second edition, InterEditions, Paris, 1977) is referred to by the abbreviation *SSM*. Notes and references to other works are placed at the end of each chapter and are cited in the text by numbers in parentheses, e.g., (4). Quotations of Artistotle are reprinted and translated in a separate chapter at the end of the book (beginning page 221); quotations are referenced by numbers in brackets, e.g., [9].

I would like to thank my translator, Vendla Meyer. At the cost of months of hard work, and thanks to the rigor and precision of her reading, she has picked out many inaccuracies and imprecisions scattered through the French text *Esquisse d'une Sémiophysique*. I wish to express here, with my gratitude, the total satisfaction I have drawn from our collaboration.

Réne Thom

FOREWORD

The work presented here cannot be said to follow directly on from *Structural Stability and Morphogenesis*. Mathematicians, in particular, will find in it neither theorem nor new algorithm (except perhaps for the metatheorem in section B, Chapter 3, which may inspire some of them). And practitioners of the natural sciences, physicists or biologists, will doubtless be disappointed to see mentioned here only classic facts, most of which have been around for a long time and are more or less common knowledge. This work is rather intended to take up the succession of a dead discipline, namely "natural philosophy". So that it can not be expected to contribute—even a little—to scientific progress, in the modern sense of the term.

To begin with, why this neologism, Semiophysics? I wanted to refer to an expression used by Jean Petitot in his thesis (1), where he presented the use of models in catastrophe theory as the "physics of meaning" (*physique du sens*). At the time, the expression hardly appeared justified to me, since physics has very precise quantitative laws (they are its characteristic feature...) whereas the same could not be said for models of signification. However, a deeper analysis of the notion of genus—in the sense of Aristotle's γένος—revealed to me a richer structure in these "semantic fields" than I had at first suspected. In these spaces there reigns a certain generativity, incomplete and abortive to be true, but present all the same.

What then is the object of this Semiophysics? Semiophysics is concerned in the first place with the seeking out of significant forms; it aims to build up a general theory of intelligibility. In fact the problem is quasi-experimental. Put someone in a projection room and project a film for him that represents some abstract morphology in evolution. Then ask your guinea-pig whether what he sees has any meaning for him, and, if so, to describe it. The hypothesis put forward here is that only certain configurations of elements really make sense and can be used as a basis for an intelligible construction that allows linguistic description. It's a

question of picking out of the spectacle stable elements in the shape of balls that will interact through contact, merge together, separate, be born and die (fade away) like living beings. These are *salient* forms. Such beings will also be able to interact at a distance thanks to invisible go-betweens like light and sound. If morphology presented only a tangled mass of teeming and ramifying forms, then it would be difficult to discern meaning in it—except by assimilating it to luxuriant plant proliferation or the chaotic disorder of a raging sea. In this direction we find what I call *pregnances*, propagating from salient form to salient form which they invest as they go; the invested form consequently suffers a change of state (figurative effect) and can, as a result, re-emit the pregnance which may or may not have been modified, (the "coding" effect).

Finally, *Semiophysics: A Sketch* consists of two parts that are fairly distinct, even though they come out of common preoccupations and are linked by the same methodology. Chapters 1 to 5 expound this theory of salience and pregnance—in which I see the conditions both necessary and sufficient for an onto-morphology to be intelligible; Chapters 6 to 8 constitute our Aristotelian journey.

It was only quite recently, almost by chance, that I discovered the work of Aristotle. It was fascinating reading, almost from the start. I knew of course that the hylomorphic schema—of which I make use in catastrophe formalism—originated in the Stagirite's work. But I was unaware of the essential fact that Aristotle had attempted in his *Physics* to construct a world theory based not on numbers but on continuity. He had thus (at least partly) realized something I have always dreamed of doing—the development of a Mathematics of the continuous, which would take the notion of the continuum as point of departure, without (if possible) any evocation of the intrinsic generativity of numbers.

The philosophical program I had in mind for Catastrophe Theory, namely the geometrization of thought and linguistic activity, was more than merely sketched out in Aristotle, it was already largely achieved. And this at the cost of a few terminological equivalences such as: ὕλη = qualitative space and the transition genus → species = bifurcation.

However, Aristotle is little thought of among mathematicians; he suffers from comparison with his master Plato who enjoys, in this domain, a reputation that is perhaps usurped. For hundreds, maybe thousands, of years, Aristotle has been *the only one to think in terms of the continuous*. To *my mind*, that is his chief merit. Naturally, this supposes a somewhat particular way of seeing geometrical entities. Neither Dedekind nor Cantor have taken that road; it is a geometry founded uniquely on the intuition of continuity. Here the segment of a straight line *is* not made up of points, but only of sub-segments. The single isolated point (say O on the axis $x'x$), exists only "potentially"; it aspires to actuality by duplicat-

ing itself in two points O_1, O_2, O_1 adhering to the left, O_2 to the right. These two points then being *distinct* even though they are *together* (ἅμα), the two half-segments so limited attain full *existence*, being in actuality (2).

This view of things, which allows the existence only of bounded closed sets of maximum dimension (balls in fact) may appear surprising. It takes up again an old idea of Poincaré's (3): to define dimension by the property a surface has of *disconnecting* three-dimensional space, by a break. One wonders whether this idea—the replacement of a point by a little oscillator that duplicates itself—might not be of a nature to furnish a useful vision of the quantum world. If I add that I found in Aristotle the concept of genericity (ὡς ἐπὶ τὸ πολύ), the idea of *stratification* as it might be glimpsed in the decomposition of the organism into homoeomerous and anhomoeomerous parts by Aristotle the biologist, and the idea of the breaking down of the genus into species as image of bifurcation, it will be agreed that there was matter for some astonishment. Besides, the very style of Aristotle, far from the axiomatic precision one might expect of a logician, is that of a thinker who is feeling his way, often retracing his steps and perpetually struggling with his object. This evidence of constant effort filled me with a feeling of immense sympathy.

I have proceeded, then, with a catastrophist reading of Aristotelian Physics (Chapter 6), followed by an exposition of Aristotelian Biology (with the problematics it is still raising (Chapter 7)), and, *in fine*, Chapter 8 devoted to the logico-semantic aspects of Aristotelian theory. It is shown how certain modern linguistic models (the continuous models of Hans-Jakob Seiler, for example) might very well enter into this framework. An appendix completes this presentation with a discussion by an informed Aristotelian, Mr. Bruno Pinchard, and the exchange of views it occasioned. To those who may suppose Aristotle's doctrine to be basically obsolete, I would point out that in him we find a philosophy that is both materialist (existence requiring a material substrate) and nevertheless governed by form and final causes. An association rarely encountered in modern times. We deal with this point in a brief Conclusion, which closes on the necessity of *restoring*—by appropriate minimal metaphysics—some kind of intelligibility to our world.

Notes and References

(1) Jean Petitot, *Morphogenèse du sens;* Vol. 1, p. 293 (last word), PUF 1985

(2) Cf. our "little phrase" *in* Met Z (13) 1039a, 3–7, quotation [2]. For a fine example of modern incomprehension of the Aristotelian point of view, see Jean Dieudonné's criticism of Φ VI, 231a, 22, in *Pour l'Honneur de l'Esprit Humain*, p. 229, Hachette, Paris 1987

(3) Henri Poincaré, *La Valeur de la science*, p. 97, Ernest Flammarion, Paris, 1914

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CHAPTER 1

SALIENCE AND PREGNANCE

A. *Introduction: the a priori problem*

One of the weakest points of the classical approach to the notion of the *a priori*—that is to say the constitution of a table of categories in the manner of Aristotle or Kant—is now said to lie in the project of legislation *ad aeternum*, whereas everything leads us to believe that the human psychic structure has changed over the course of time. Man springs from animal, and yet it would be surprising to attribute to animals the same cognitive capacities as to man. In this sense, all epistemology must be "genetic": it must take into account the effect of evolutionary transformations to which the human lineage has been subjected for thousands of years.

Nevertheless, this finding should not lead to total relativism. Even the most "evolutionist" of the epistemologists of evolution is forced to admit the perennial nature of time, this framework within which the process to be described is actually happening. (Who is there to tell us of the intrinsic variations of time in ages past?) In the same way, the *a priori* constant validity of the structure of Euclidean space, even space-time, will be conceded for our purposes. Objections raised to the Kantian apriority of Euclidean geometry after the discovery of non-Euclidean geometries, and the theories of twentieth century physics (restricted and general relativity, quantum mechanics) appear to me irrelevant to the problem before us, for they deal with an ontological region (infinitely small and infinitely large, singularly reunited in fundamental physics) which lies outside the usual cognitive activity of ancient man. Such objections are inspired by the spirit of logicism in an attempt to provide the categories with a formal *a priori* basis.

So it is in our usual space-time, basic framework of all human experience, that the analysis of the original psychic mechanisms of our species which we propose to construe, will have its roots. These basic tools of

ours will be borrowed from the formalism of exact sciences: field propagation in physics, discontinuities (phase states in matter), as well as a strictly biological *a priori* linked with the notion of individual (the notion of "pregnance"*). Later on we shall extend these mechanisms to abstract spaces of a semantic character. But our approach has nothing to do with the search for a logical foundation: it is a physicalist approach, aiming to describe a "psychic universe" which, in many respects, *simulates* the outside universe of things and processes. The notion of "truth", from this point of view, is but a particular "pregnance" related to the Thomist adequation of mind and objects. The propagation of this pregnance in the universe of propositions is described by formal logic. However the big problem—in the philosophy of language—is not that of truth (a matter of accident, *Sumbebèkos* as Aristotle would say), but that of semantic acceptability, defining the world of what is possible, which contains the (eminently variable) subset of what is real. We will not be looking for the foundation of geometry in logic. On the contrary, we shall be seeing logic as a derived activity (a secondary one, when all is said and done, in the history of the human mind), a rhetoric. We shall be trying, not so much to convince, as to suggest representations and to extend the intelligibility of our world. Instead of building geometry in a logical manner, we will seek to base what is logical on geometry. So we will get this very general pattern of a world made up of salient forms and pregnances—salient forms being objects, very often individuated, that are impenetrable to one another, and pregnances being occult qualities, efficient virtues that emanate from source-forms and invest other salient forms in which they produce visible effects (figurative effects).

This very flexible schema does not, of course, lead us to a univocal world vision. But it does permit a fairly strict classification of the main types of interaction: salience $\overrightarrow{\leftarrow}$ salience (collision), pregnance $\rightarrow$ salience (predication and figurative effects), pregnance $\overrightarrow{\leftarrow}$ pregnance. This last case is the most mysterious of all; catastrophe schematization alone would seem to have some general bearing here. We will draw examples of these main types of interaction from both the world of thought (the semantic universe) and the objective world of science (physics and biology). This schema will be criticized on the one hand for being too variable and fuzzy (whence its pragmatic inefficacy) and, on the other, for its limited and anthropocentric character. I am quite prepared to accept this last objection, for what indeed can one hope to attain other than a local knowledge? But to provide a theory with a basis solid enough to

* The French term *prégnance*, particularly in the special sense used by René Thom, is difficult to put into English. I apologize for translating it rather flatly by "pregnance" but hope that the reader will have adopted it into his everyday language by the end of the book (Translator's note).

bear comparison with the empirical validity of Euclidean geometry would be no mean achievement, it seems to me. Aristotle's first philosophy came "after physics", μετὰ τὰ ρυσικά; I wanted to describe here something that might be called "protophysics", source and reservoir of all permanent intuition, of all those archetypal metaphors that have nourished man's imagination over the ages.

B. Salience

The primary experience in any receiving of phenomena is discontinuity. But discontinuity presupposes the continuous. As our first experience of the continuous is that of consciousness, i.e. that of time, the most original auditive discontinuity will be, for example, the eruption of a sound in the midst of silence. The tinkle of a bell is perceived as an autonomous form, filling the gap between two empty zones of silence. I shall call *salient form* any experienced form clearly separate from the continuous background against which it stands out. If we move from time to space, then a salient form can be said to be any visually perceived object clearly distinct from and contrasting with its background, the "substrate" space in which the form dwells. Generally, a salient form that is seen will have an *interior* in the field of vision, and will present a boundary, its apparent outline.

Empty forms, such as curves in a plane, surfaces in a three-dimensional space, can hardly be looked on as "forms", lacking as they do the character of autonomy, of individuation, proper to beings perceived as legitimate entities. For them we shall keep the term of *features* (1).

The simplest feature is the punctual discontinuity geometrically represented by a point dividing the real straight line $\mathbf{R}$ into two half-lines —+—. Timewise, it would be the onset of noise in relation to silence. Visually, the point could separate two regions having different visual characteristics, two colors for example.

In the plane $\mathbf{R}^2$, any finite set of isolated points, any curve, may be considered as a *feature*. The same goes for (non-closed) surfaces in $\mathbf{R}^3$. The simplest individuated forms are *balls*. In dimension one it is the tinkle of a bell, in dimension two the disk circumscribed by a simple closed curve, in dimension three the ball inside its boundary sphere. Sometimes the interior can be very thin and there may then be a certain ambiguity as to the nature of the form; should we rather look on it as a feature? Take lightning, for instance.

Salience may present a hierarchized aspect related to "contextual effects" between forms. For example, a gap in a periodic sequence of "pips" will be felt to be salient. (There exist neurophysiological criteria

for this kind of phenomenon, known as the P-300 effect (2).) Generally speaking, every discontinuity is translated *into a discontinuity* in the subjective sensorial state (sometimes with enormous amplification). This is a very general phenomenon in propagative partial differential equation theory, the wave equation, *for instance*. The discontinuity of a solution is then propagated by the Hamilton-Jacobi equation associated with the *symbol* operator. However, even in the most general couplings between systems S and S', a *discontinuity* in the state of S will usually produce a discontinuity in the state of S'. (This is what, in a nutshell, I have called the "principle of catastrophe contagiousness".) Subjectively experienced discontinuity *is but the echo within* an organism of a physical discontinuity outside it. This argument should carry some weight as an answer to idealism, which claims that the mind can have no knowledge whatsoever of *things*. *In this* permanence of discontinuity throughout the course of its propagation, some have even discerned a possible objective basis for the notion (otherwise so confused) of information. Certainly, Peircean "*Firstness*"(3) may be perceived as the pure manifestation (reduced to its bare existence) of a shock inflicted on our psychism by the outside world. As we shall see in Chapter 8, the impact of discontinuity *is doubtless* no stranger to Aristotle's *logos apophanticos*, that which gives semantic autonomy to a nuclear sentence.

Many of the discontinuities we perceive probably do not give rise to judgments; *for that it is* necessary for some pragmatic or communicatory interest to focus our attention on the *fact*. We will come back later to this point which is linked with the notion of pregnance to be introduced in the *next section*.

One difficult question in the theory of salience arises from the notion of *individuated form*. It is perhaps permissible to see in the isolated *point on the line* $\mathbf{R}$ a sort of "organizing center" of the form defined by the interval ⊢—⊣ . (Vary ε from 0 to 1 *in* $x^2 = \varepsilon$.) Mathematically speaking, the individuated form appears to be more stable than the "line". But *there may* be degrees in the individuated character of a form. For instance, a simple arc separating two colors that run into each other at the edges presents a certain individuation. The (topological) *connectedness* of the line appears as a necessary general condition of individuation. There are exceptions, however: (1) when the non-connected entity answers to a functional definition (e.g., place laid on the dining table, business concern in economy, etc.); (2) when the unity of a form is re-established from suitably arranged fragments. We are dealing with mechanisms of perception generally linked with the prolongation of straight lines, or with the three-dimensional interpretation of a plane figure. Gestalt theorists have furnished abundant literature on these phenomena (4). I would be tempted to see in these apparent exceptions a

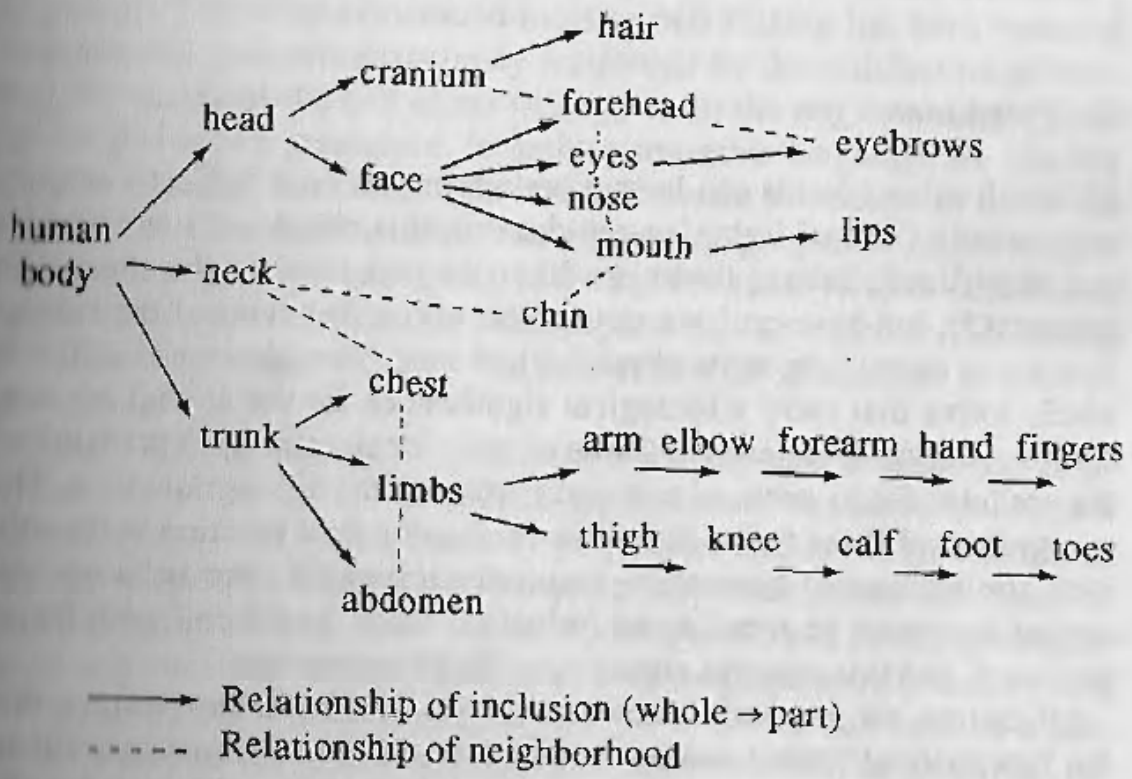


Figure 1.1

further justification of the principle of the connectedness of forms, for they show how strongly the mind is attracted to connection.

Another major problem attached to form individuation lies in the decomposition of a form into "features". The human body, for example, is decomposed, as an individuated form, into parts that can be presented in a hierarchized graph (Figure 1.1).

It may be thought that this decomposition is not an arbitrary one, and that it reflects to a certain extent the ontogenetic process of embryology. Conversely, an individuated form may be "annihilated" by *analysis* proceeding from the whole to the parts. This would amount to saying that there can be no individuation without a certain form of "concept", that is to say a class of equivalence between forms referent to the same concept. As the Boeotian would say when confronted with a picture of modern art, "It doesn't mean anything". However that may be, the frequently hierarchized character of individuation is evident in the preceding example.

We also have to consider separately the case of ramifying forms (such as a spark, fungus mycelium, etc.) where individuation is diluted in the

topological complexity of the teeming form. Here again we are coming close to the domain of "pregnance".

C. Pregnance

Although salient forms can have a certain impact on a subject's sensory apparatus (a flash of lightning can dazzle), this effect remains transient and short-lived. Salient forms are likewise registered in the short-term memory(5), but have no long-term effect on the behavior of the subject (human or animal) or on its physiological state. The situation is different where forms that carry a biological significance for the animal are concerned. Among these are the forms of prey for the (hungry) predator, of the predator for its prey, of a sexual partner at the appropriate time. The recognition of these forms gives rise to a very ample reaction in the subject: the freeing of hormones, emotive excitement, and behavior designed to attract or repulse the inductive form. I will call such forms *pregnant*, and this specific character of theirs *pregnance*.

Of course, all pregnant forms are *ipso facto* salient. But we note that the "pregnantial" effect can be triggered in a subject by a sensory stimulus with very little "figuration", an olfactory stimulus for instance. So that there are at least some grounds for dissociating the "pregnance" from the salient forms which start it off. I believe that the failure of classical Gestalt theory to make this distinction is a serious shortcoming, the gestaltist concept of *Prägnanz* having more to do with the individuation criteria of a perceived form. Nevertheless we shall see that when animal pregnance is generalized in the direction of human conceptualization, "conceptual or individuating pregnances" will be revealed, the nature of which is close to "salience". In higher animals (birds and mammals, to be more precise) the pregnances encountered are rather few: hunger, fear, sexual desire. But because of their connection with Pavlovian conditioning, these great biological pregnances affect the whole of behavior.

D. Pavlovian conditioning: subjective investment

Let us recall Pavlov's classic experiment. A nice piece of meat is presented to a hungry dog and a bell is rung at the same time. When this association is repeated often enough, the sound of the bell is in itself sufficient to bring on in the dog behavior related to an appetite for food

(it will salivate). We will interpret this fact in terms of pregnance and salience.

The meat, a salient form, is also *pregnant:* it carries an alimentary pregnance. When the association meat → bell ringing has been repeated often enough (and simultaneously *reinforced* by the satisfaction of hunger), the sound of the bell alone will appear to the dog as a salient form rich in alimentary pregnance. In anthropomorphic language, we can say that, for the dog, the tinkle of a bell will evoke the image of food—of meat in this particular instance. The alimentary pregnance of the meat is said to have spread by contiguity to the salient auditive form constituted by the ringing of the bell. We shall express this as follows: The salient form that is the sound of the bell is *invested* by the alimentary pregnance of the meat.

Classic conditioning experiments (6) show how this process can be iterated: the tinkle of the bell can act as an inductive source to invest a second salient form with alimentary pregnance, and so on. (It remains to be seen whether a chain so constructed can stretch very far: feats of training higher animals show that it is possible to build up fairly complicated sequences of "actions" invested with pregnance, each action then being equivalent to a perceived salient form.) So we can look on a pregnance as an invasive fluid spreading through the field of perceived salient forms, the salient form acting as a "fissure" in reality through which seeps the infiltrating fluid of pregnance. This propagation takes place according to the two modes "propagation by contiguity" and "propagation by similarity", which John Frazer used to classify the magical actions of primitive man in *The Golden Bough* (7). We shall come back later to the linguistic implications of this pregnance propagation. For the moment let us simply observe that contiguity and similarity call, respectively, on the topology and geometry of our macroscopic space; in this sense, Pavlovian conditioning can be said to have an underlying geometrical basis.

Pavlovian conditioning is often considered to be a pure manifestation of neurophysiological (or psychic) automatism. That is the impression given by behaviorists like Skinner. It was probably not Pavlov's own opinion, for he was conscious of the profoundly purposive character of this phenomenon. The mere fact that a salient form placed before reinforcement is more quickly and thoroughly invested than if it comes "after", shows, as it were, a desire to simulate physical causality (8) (at least, that is, if one is a realist with regard to causality). Hume would say, on the contrary, that we believe in causality because we have been conditioned phylogenetically to do so by the regularity with which phenomena succeed one another in the physical world. Be that as it may, the attempts of neurophysiologists to explain Pavlovian conditioning by

some acquired modification in the states of neurons or synapses are hardly convincing because they do not tackle the initial question: What is there to distinguish the way the organism deals *with* a pregnant form from the way *it deals* with a form which is only salient? Why does a pregnant form invest its neighbors whilst a simply salient form does not?

E. Formalization of subjective pregnances

If we suppose that A = meat, B = tinkle of a bell, the conditioned state of Pavlov's dog can be represented by the arrow

$$B \rightarrow A \text{ (meaning: where } B \text{ is a sign of } A)$$

We shall say that form B *refers symbolically* to form A. Here I am making use of a notion taken from the axiomatics of G.G. Granger (9) extended from a human situation to an animal one. If, moving on from B, the pregnance has invested a third form C, we can write:

$$C \rightarrow B \rightarrow A$$

and conclude that the transitivity rule applies:

$$C \rightarrow A.$$

This shows that, at a given moment, the state of a subject with regard to a given pregnance can be described by such a system of arrows between forms (what algebraists call a category, in mathematics) (10). We shall denote Γ_p the category associated in this way with a pregnance P. These "pregnantial" categories are not arbitrary. They satisfy the following property:

PROPOSITION. *A pregnantial category Γ_p has no cycles.* Here follows what I would not be so rash as to call a demonstration of the proposition, but rather the argument that does furnish some justification for it.

Let us denote by $R(X)$ the set of physiological reactions triggered in a subject when it perceives the form X. If

$$B \rightarrow A$$

it is reasonable to suppose that B provokes less reaction than the form A; hence $R(B) \leq R(A)$ as a subset.

Then if we had a cycle of the form:

$$A_0 \rightarrow A_{n-1} \rightarrow A_{n-2} \rightarrow \cdots \rightarrow A_1 \rightarrow A_0$$

we could deduce from it that

$$R(A_0) \leq R(A_{n-1}) \leq R(A_{n-2}) \leq \cdots \leq R(A_1) \leq R(A_0)$$

So all the A forms would produce the same set of reactions, which, from the behaviorist point of view, means that they all have the same "signification".

COROLLARY (pure algebra). On every pregnantial category Γ_p, there exists a function $\Im$ (pregnance intensity) such that if $X \rightarrow Y$ in Γ_p we have

$$\Im(X) < \Im(Y).$$

F. *Source forms and individuating pregnances*

DEFINITION. A form S extreme in Γ_p, that is, for which there exists no other form Γ such that $S \rightarrow T$, will be called a *source form* of P. The function $\Im$ is maximal on every chain containing S, at which point it reaches its maximum.

In a biologically well-regulated situation, every symbolic reference that can be traced back to a source form encountered in reality leads to reinforcement: alimentary satisfaction or "punishment" for regulatory pregnances such as fear. In the latter case it is a matter of reflex avoidance of the source form seen as dangerous (a predator, for instance).

A category Γ_p does not show only converging arrows ; if such were the case, a category Γ_p, not containing a cycle, would be a reunion of trees (considered as an oriented graph $\rightarrow$ where the symbol $B \rightarrow A$ means that B is a sign of A). Each tree then has a single source form S. We shall say in this case that the pregnance P is *individuating*, or, in other words, that P is the *individuating* pregnance of the source form S.

We have seen earlier on (section B) that an organism generally has an individuating pregnance which implies its "salient features" or significant parts; we shall see how, in human linguistics, a peculiar localizing pregnance may even be attached to every locality.

A pregnantial category, though bounded "above" by its source forms, does not generally have lower-boundary elements where $\Im$ would be minimal. (More precisely, every salient non-pregnant form could be said to have zero $\Im$ intensity.) The propagative nature of Pavlovian conditioning shows that any pregnance can be modified in its least pregnant forms at its lowest levels of intensity.

The structure of a pregnance can be visualized by changing the sign of $\Im$, supposing, for example, that $V = k - \Im$, where V would be seen as

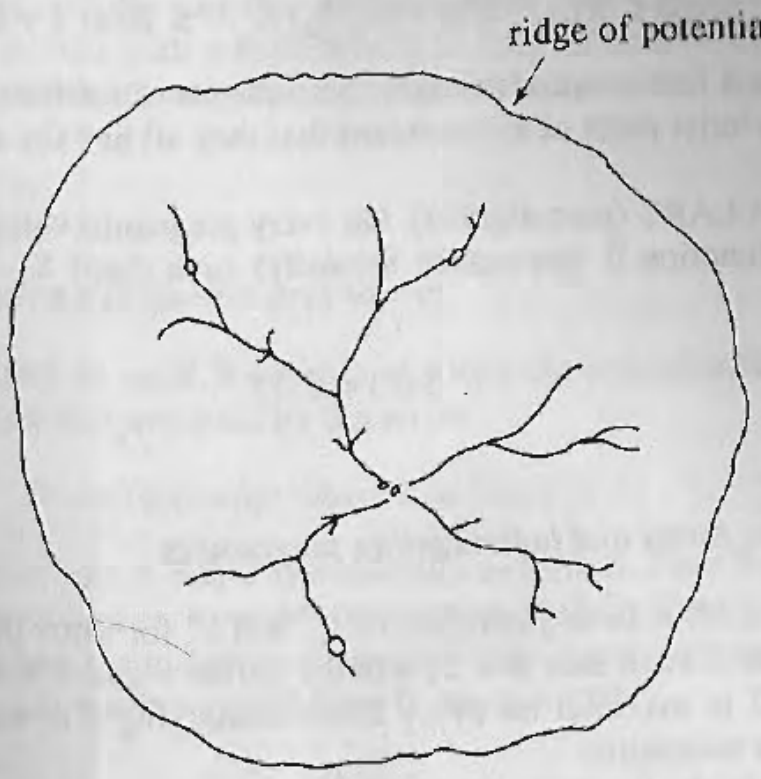


Figure 1.2 Pregnance as a potential well

a potential. The global structure of the category Γ_p could then be seen as a *potential well*, the depths of which would be occupied by the source forms. This potential well can be considered, more exactly, as an "epigenetic landscape" in Waddington's sense of the term(11); the *rivers* flowing down convergently are the ridges of the graph Γ_p (Figure 1.2).

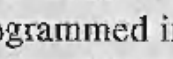
G. Genetics and pregnance

One wonders, then, whether the "generic" structure of a pregnantial category is genetically determined, in particular whether the source forms of such a pregnance are genetically programmed. For higher animals, the answer must surely be no. While it is easy enough to imagine that there may be innate signals of an olfactory nature (these being chemical), it is doubtful whether genetics alone would be able to *code* a visual form. An object in three-dimensional space has an infinity of apparent contours, and neither DNA nor any other chemical support contained in

the egg would ever hold enough information to code them all. Whence the necessity of invoking *cultural* transmission, linked with the social or family organization of the community.

H. Social animals and communication

The problem of cultural acquisition is particularly acute in gregarious animals. We can lay down as a principle that social communication has a regulatory function in the body of society. Consequently the signals used in a collectivity are *vectors of pregnance;* they transfer a pregnance from one member of the community to another, or to several others, so promoting the collective behavior required to capture food, to ward off predators or escape from them. The *capacity* to emit certain types of signals by means of appropriate organs is genetically programmed. The formation of these organs can here be explained only with reference to the global morphogenetic schema of a species.

What genetics *can* program in a pregnance, on the other hand, is the global topological structure of the potential well and in particular the global schema of its descending valleys. Thus divergence leading to a ramification of source forms may be programmed in advance  . We shall see (in Chapter 2) that the origins of human language are to be sought in this direction. From this angle, the source form would be defined, not as a visual form, but as the abstract abode of a category Γ_p, a "black hole" to be filled with the first sensorial experiences of the newborn infant. Thus we find in global pregnance organization a sort of "tendency" to diverge or to converge, more or less genetically programmed; the filling-in of the sinks, of the "black holes", would be more of a cultural acquisition (or at least an "epigenetic" one). The phenomena of *imprinting* brought to light by ethologists (12) can be understood in this way. We can also find here an explanation for those very strange "supranormal releaser" phenomena. Take the goose that prefers to sit on a rugby ball rather than an egg of its own species: the visual form of the species not being genetically coded, all that is programmed is a general ovoid shape linked with the "body schema" and the brooding state; and better, after all, to choose a big egg than a little one.

It would be as well to draw a distinction here between imprint and conditioning. An imprint is a genetically programmed phenomenon producing an irreversible effect that no subsequent experiment can undo (I owe this precious observation to Doctor Jacques Miermont). Very strongly marked in birds, where it was discovered long ago, this phenomenon is less evident in mammals. In man, the acquisition of language may be considered as the effect of an imprint that can be

modulated by social environment; it is true that the mother tongue is mnemonically very stable. This point will be considered in the next chapter.

We have to conclude that the innate morphogenetic schema contains *a priori* the social structure of the species. This is particularly evident in the case of social insects (ants, termites, bees) in which the very constitution of the organism depends on the social role (or caste) of the individual. Algebraists say that within a category there are identical morphisms $A \rightarrow A$; any *signal* is to be associated with the identical morphism of a source form. When a symbolic reference is traced back to a source form, no further association is possible and the only possible issue is generally a motory one: to carry out the regulatory reflex that will bring satisfaction. In a social group, one individual's encounter with a source form S may give rise to a dilemma: whether to pursue the "individual interest" which consists in using the regulatory reflex that will result in selfish satisfaction, or to follow the altruistic community strategy by uttering the cry that will carry the pregnance S to the other members of the community; such a cry is then the signal by which the pregnance P of S experienced by individual 1 can be transferred to another individual 2. One example of this is the cry of alarm transporting the pregnance fear. It sets in motion the defensive reflex of banding together or of taking flight, but it also incurs the risk of attracting the predator's attention. In the case of an alimentary pregnance, the dilemma facing the individual who has come upon a source of food consists in whether to keep the information and benefit for himself or, on the contrary, to communicate the news to the group so as to share the good fortune. (This dilemma exists well and truly in our society. Witness the scruples most honest citizens have in making a true declaration of their taxable revenues.) In presenting this strictly regulatory vision of animal language, I expect to hear the usual objections put forward in similar instances: that it is an unduly reductionist view of language, since language is used in so many other situations with quite different aims—mating or parading songs, for example, all varieties of affective demonstration (aggressivity between individuals, marks of affection, etc.). I do not, of course, deny these other activities: affectivity, be it pleasurable or painful, is a motor of pregnance propagation. Unless an association $B \rightarrow A$ is reinforced, it fades out after a while (13). Thus affectivity serves to "sprout arrows" in the category (cf. Chapter 4, section C); it can also be expressed directly, thus serving to inform the rest of the community of the emitting subject's affective state.

The existence of a signal that can be given to transmit the pregnance S raises new problems. First comes the question we have already dealt with: Is the source form determined genetically, or is it acquired through

culture? The example of wild geese (as well as of certain primates), whose cry of alarm varies according to the nature of the predator (aerial, terrestrial or arboreal) (14) seems to show that the signal is determined more by a collective defense reflex than by a strictly defined form. Again, the fact that certain primates raised to sexual maturity in isolation are then unable to perform the sexual act would indicate that in these species cultural acquisition is indispensable, even for such a biologically important regulation as reproduction.

I. Sign and genitive

One might indeed wonder with respect to the alarm call, if there is a genetically programmed source form of predators. *Many* species (luckily for them) are unaware of the identity of their predators (especially the rare ones); and, when the hunt is always successful, it is hard to imagine how the victim would be in a position to picture the hunter to himself. One may guess that when a community member is caught and torn to bits by a predator, the remains of the meal will have a repellent effect on the surviving members so that the place where it happened will become a "black spot" in the territory, somewhere to be avoided, the object of a repulsive localizing pregnance. Should the predator reappear in the same place in quest of the same prey, he will be imbued with a repellent pregnance due to his very presence there. When the cat of the house proudly brings indoors the mouse it has caught outside, it probably does so (whatever its owners may think) not so much in the hopes of a reward as to clear away from mouse territory the corpse or remains that might reveal a killer's visit. Man's horror of death might well find its ancestral origin in just such a situation.

A problem perhaps essential to understanding the origins of human language is the question of "clues" or signs. If a member of the collectivity perceives a sign left by some familiar marauder that preys on its kind, a spoor or a dropping for example, it will be tempted to utter the cry of alarm that will warn its fellows of a dangerous presence nearby. Among the salient forms canonically attached to the predator are the signs (tracks, excreta) which it makes and leaves on its passage. Now is the prey to give the alarm call just because it perceives a sign, when the predator itself is absent? Raising the alarm is a serious matter, for it interrupts the normal activity of the community (pulling the alarm-cord in a train, without due reason, will incur a fine). An alarm that is sounded too often when there is no real danger will eventually lose its impact (cf. the shepherd boy who was always crying "Wolf!" in La Fontaine's

fable). The "genitive", a syntactical form that denotes the proximity of a being whilst denying its immediate presence, perhaps made its appearance in order to resolve this dilemma. The alarm was in fact given upon sighting a trace but with an affix to say that the predator was not actually there, thus permitting a more graduated defense strategy.

However that may be, the presence of a signal associated with a source form S can be considered as a first form of *concept*, class of equivalence between salient forms. Those forms are equivalent whose perception causes the signal to be given.

J. Subjective investment and objective investment

The transmission of pregnance by signals in animal collectivities introduces an essential distinction into the analysis of pregnance functioning. Let us compare the situation of Pavlov's conditioned dog with that of the group sentinel giving the alarm cry on sighting a predator. In the first case, the form "ringing of the bell" is said to be imbued with alimentary pregnance. But this transformation only occurs in the psyche of the conditioned dog. Nothing in the phonic structure of the signal has changed intrinsically; the only objective aspect concerns the dog itself, the subject, whose psyche is going to run through the whole associative chain of the category Γ_p in order to reach the source form. (When this chain includes actions on the part of the subject, then we have the principle of training or dressage.) There is then no intrinsic modification of the form; the subject, on the contrary, undergoes a considerable change when inverted by the subject's the "objectively" investing pregnant form, as may be seen from its physiological state (the dog salivates). In the case of the look-out raising the alarm, there is also an objective investment of the animal by the pregnance "fear"; the animal emits the cry of alarm, a salient form which is also a pregnant form for the group.

Thus the pregnant character of a form is always in theory relative to a receiving subject (or group of subjects). But for the "trigger" character of the pregnant form we can provide a model inspired by the "tunnel effect" well-known in quantum mechanics. The "ground" state of the receiving subject may be considered as a non-absolute minimum, surrounded by a ring of basins the bottoms of which are lower than the ground state. The perception of a pregnant form creates a "tunnel effect" which precipitates the representative point into a peripheral basin, thereby liberating energy. The indetermination of pregnant forms can be looked on as due to the attraction held by a pregnant form in a space of forms where distance would be a sum of Euclidean space-time distance and a Gestaltist distance (difference in the aspect of forms). It might

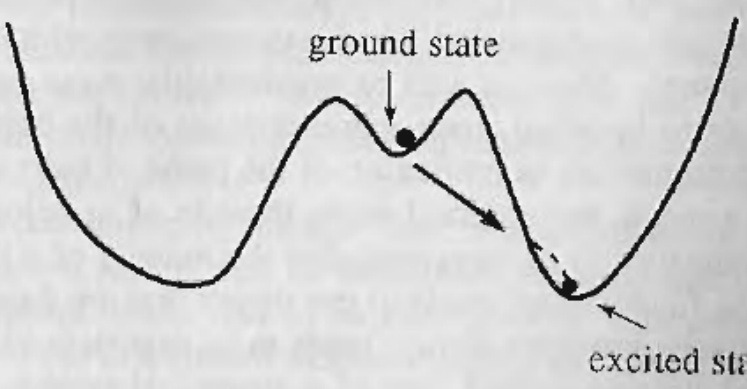


Figure 1.3 Tunnel effect, due to the apparition of a pregnant form, on a sensitive subject

seem paradoxical that the excited states, in this model, should be situated below the ground state, in contrast to what happens in a physical system, like a hydrogen atom for example (Figure 1.3). This is because in living beings the excited states have a part to play in biological regulation and determine regulative action. *Now affectivity can be seen as an agent distorting regulation structure.* Pregnance, which is nothing but the memory of earlier satisfaction or pain, is, at the same time, the anticipation of similar satisfaction or pain. The action set in motion by the pregnance aims to obtain this satisfaction or to avoid this pain.

In the potential well a "virtual" affectivity like the one that comes from anticipation has an effect on the form of the potential opposite to the effect linked with satisfaction (positive result of regulative action). The hungry animal in search of prey is excited; once the prey has been caught and ingested, affective satisfaction lifts the level of the excited state basin and eventually annihilates it. The animal then returns to the ground state (it falls asleep). When it awakes and begins to feel hungry again, the well of the excitation basin re-forms, below the ground state level (cf. Chapter 4, section C). This phenomenon is related to the paradox of the hungry predator, one with its prey, and the model of the predation loop (perception catastrophe described in *SSM*). This model gives an account of the interaction between predator and prey; during the bimodality period, their regulative potentials are in opposition to each other. We will draw a distinction here between "potential" investment by a pregnance (the hungry animal looking for its prey is *potentially invest-*

ed by hunger) and "actual" investment, which comes in after the perception catastrophe (recognition of an external prey which the predator starts to pursue).* Men (as well as prehominids) were early incited by group living to build up some representation of the behavior of their kind, a representation, in particular, of the paths of their affective regulation. As a result, any external entity thought of as being individuated tends, by empathy, to be imagined after the manner of a *living* being. It is one of the fundamental tenets of our theory that the Aristotelian opposition *sub*stance-predicate always tends to be experienced as the opposition ground state ↔ excited state of a dynamical system. The predicate is then associated with the transition and symbolizes the qualitative (perhaps even quantitative) characteristics which belong to it. From this angle, the general formalism of all intelligible ontology can thus be characterized.

K. Intelligible ontologies

1. An intelligible ontology is characterized by a space where all the beings considered reside: the *substrate* space. We shall see it as a Euclidean space (or a differentiable manifold) of arbitrary dimension B.

2. Within B the beings of this ontology are divided into two classes: salient forms and pregnances.

A salient form is a *closed set* F on the space B. If the form is individuated, it will have an interior $\Im$, where the closure $\overline{\Im}$ of $\Im$ is a ball. The individuated form is said to be "organized" if it has a canonical model of closed sets contained in $\Im$ which are themselves organized, the total organization being described by the tree Γ_p of an individuating pregnance. Two distinct salient forms are topologically disjoint. *Pregnances* are non-localized entities emitted and received by salient forms. When a salient form seizes a pregnance, it is invaded by this pregnance and consequently undergoes transformations in its inner state which can in turn produce outward manifestations in its form: we call these *figurative effects*.

A frequent (though not universal) case of figurative effect is the re-emission by an invested form of the same pregnance that invests it. Take for example the phenomenon of contagion: an infection contaminates healthy subjects who may in turn become contagious and re-emit the same infection in their environment.

* In Aristotelian terminology (cf. Chapter 6), potential investment would be a privation (*stərèsis*); the apparition of the prey triggers "aim" (*entelecheia*), and so movement (*metabolè*).

In this case the infection is always supposed to have some material support: virus, bacteria, uni- or pluri-cellular parasites. But ailments of a psychic character are known to have been transmitted just by imitation (15). With animals, communication is often achieved by means of undulatory sound or light signals.

The ideal of contemporary science—and of positivism—is to reduce everything to salient forms, with no interaction allowed other than collision between salient forms, and to do away entirely with pregnance. It manages to do so (as in quantum mechanics) only by foregoing intelligibility, for the particle, which is a salient entity, is identified with the field, which is a pregnantial entity. Quantum mechanics does however give us the notion of exchange particle, monstrous hybrid born of salience *and* pregnance. It is worth noting, however, that Pauli principle fermions take after salient forms in their impenetrability, whereas bosons are typically "radiative" (like the photon).

We note that this presentation of intelligible ontologies can be made at a *pre-verbal* level: intelligibility is thus a property of phenomena (taken as Gestalten) prior to any conceptualization in the strict sense.

But the main interest of the "Semiophysics" sketched here lies in the study of language and of the qualitative, non-mathematized sciences based thereon.

NOTES AND REFERENCES

(1) **Lines.** This observation, decrying curves and surfaces *in* favor of volumes, can be likened to Aristotle's commentaries on the use of geometrical entities in the description of nature. "How (...) could a line or plane be animate?" Quotation [20] Met M 1077b 29–30.

(2) The P-300 effect describes a lowering of electro-encephalogram activity that occurs between 200 and 300 milliseconds after the impact of stimulus. It is thought that this effect shows a wakening of attention in the higher centers of the cortex. Mentioned in *Audition* by P. Buser and Michel Imbert, Hermann, Paris, 1987, p. 322

(3) *Collected Papers of Charles Sanders Peirce*, by Charles Hartshorne, Paul Weiss and Arthur W. Birkes, Cambridge (Massachusetts), Harvard University Press, 1935–36. We shall come back to Peircean Thirdness in Chapter 8, section E.

(4) Our use of the word *pregnance* comes of course from the German *Prägnanz*, which we owe to the Gestalt theory school. The vocable is said to be due to Max Wertheimer, who theorized its significance in "Untersuchungen zur Lehre von der Gestalt I", *Psychische Forschung*,

1922, I, 47–58. We quote W. Khöler's *Die physiker gestalten in Ruhe und in stationären Zustand, Eine naturphilosophische Untersuchung, Erlangen,* 1920: "Where a physical form of homogeneous material properties can yield sufficiently to the systematic forces acting upon it, it seems to be a general rule that very simple and regular spatial arrangements are reached in the stationary state.

This behavior of physical systems in their progress towards stationary states has been emphasized by the physicists P. Curie and Mach. Curie writes that before natural processes can take place "it is necessary that certain elements of symmetry be absent. *Asymmetry* creates natural processes".

The law exemplified in cases of this sort may be called the tendency towards simple Gestalten, or the law of Prägnanz—provided, of course, that we consciously leave the terms somewhat indefinite as a means of reminding ourselves that the theoretical physical problem is as yet unsolved.

This designation comes from Wertheimer, not as a description of inorganic physical behaviour, but of phenomenal and therefore also of physiological process-structure. Nevertheless it is possible to apply the terms to physical phenomena also, for the general tendency and line of development observed by Wertheimer in psychology and designated by him as the law of Prägnanz is obviously the same as we have here been discussing."

Extract from *A Source Book of Gestalt Psychology,* ed. Willis D. Ellis 1938, re-edited Routledge and Kegan Paul, London, 1969.

This very interesting text shows how these authors were perfectly aware of the theoretical breadth of their conceptions, since they were hoping to make use of an "isomorphism" of psychological processes with underlying neurophysiological processes (in conformity with an old idea of B. Riemann's). Present-day theoreticians who speak of self-organization and of the order of dissipative structures as though they were something new are doubtless unaware of how old these concepts are. We simply observe that if Pierre Curie is quoted here there is perhaps a misunderstanding. For the phenomena mentioned are in *violation* of Curie's principle, rather than examples of its application. In any case it is probably true to say that the problem considered here is not much nearer a solution than it was in 1922.

It is understood that we are not using the term "pregnance" in the same way as the Gestalt theorists. Considered dynamically, as above, it is more a question of factors that *trigger* and *regulate* progression towards the stationary state than of the morphology of the stationary state itself...

(5) The distinction between *short-term* and long-term memory is a piece of "folklore" knowledge in neuropsychology. Consult on this point R.E. Ornstein's *On the Experience of Time*, Penguin Books, London, 1969.

(6) There is an immense amount of literature on Pavlovian conditioning. I shall mention here, for its usefulness, J.F. Le Ny's *Le conditionnement et l'apprentissage*, PUF, 1961, 1980 reedition. Information is to be found in this book on:

—*simple* conditioning, p.25
—*(reinforced)* propagation on secondary sources (secondary reinforcement), p. 151
—the role of similarity between induced forms, pp. 88–90.

(7) Sir James George Frazer, *The Golden Bough — a Study in Magic and Religion*, 12-volume edition, 1907–1915, abridged in one volume 1922, MacMillan, New York, 1951.

(8) For the influence of delay between conditioning stimulus and reinforcement, see Le Ny quoted in note 6, p. 33. The *optimum* duration between the end of the induced salient form and the beginning of the pregnance stimulus is 0.5 *s*; no conditioning stimulus can be obtained *after* reinforcement. This is an example of the *simulation of causality* presented by Pavlovian conditioning.

(9) The axiomatic idea on significant association was suggested to me by Gaston-Gilles Granger's *Langages et épistémologie*, Klincksieck, Paris 1979; the author there expounds a set of axioms on symbolic reference.

(10) **Category theory.** The word category as it is used in modern algebra has nothing to do with categories *in philosophy* (in the sense of Aristotle and Kant). The term appeared in 1945 in a "seminal" article of Eilenberg-Mac Lane (*Transactions of the American Mathematical Society*, 58, 1945, 231–294). We find it presented in *Foundations of Algebraic Topology*, by S. Eilenberg and N. Steenrod, Princeton University Press, 1952, pp. 108–110. Behind a superficially terrifying formal apparatus lies a notion that is really quite simple: namely, the set of paths that can be described in an oriented graph (accepting punctual paths which do not come out of a vertex). I do not urge the reader to study this theory which has since enjoyed a considerable formal development. It will be sufficient for him to know its definition and geometrical interpretation *in terms* of oriented graphs, or particularly those issued by discretization from an underlying continuous dynamic system.

(11) **Waddington's epigenetic landscape.** This metaphor (which played a primordial role in the origin of Catastrophe Theory) first appeared in

C.H. Waddington's *Organizers and Genes*, Cambridge University Press, 1940.

(12) **Imprinting**. This classic phenomenon was discovered by Heinroth (1911) in geese. Since then, it has been popularized by KLorenz. Cf. *Animals as Social Beings*, Adolf Postmann, Harper Torchbooks, Harper and Row, New York 1961, p.113.

The imprint is characterized by its irreversible nature, associated with a limited period of sensitivity. It has a very marked effect in birds where the sensitive period lasts for 6 to 24 hours after hatching. It seems as though the separation of hatching out of the egg has to be immediately compensated for by a very strong attachment to the visual image of the parent. In (viviparous) mammals, where the newly-born is in very close contact with the mother's body, the imprinting mechanism has a more graduated form closer to Pavlovian conditioning.

(13) **Extinction**. See Chapter 4, pp. 70–73 in Le Ny's book referenced in note 6. The phenomenon of relatively quick recuperation of an investment that has disappeared through non-reinforcement, and reactivated by subsequent association, could be interpreted as due to a residual lowering of the threshold separating the satellite basin of the invested form from the minimal basin of the source *form*. Generally speaking, a repeated association between two non-pregnant salient forms (*A*) and (*B*) produces a topological modification by contiguity-similarity of the space of salient forms: (*A*) and (*B*) come close together, with the result that if one of them (*A*) becomes pregnant, the other (*B*) will also share the pregnance. Extinction through absence of reinforcement may be interpreted as a moving away from the source form; and if an invested salient form (*X*) is associated with another salient form (*Y*) in the absence of reinforcement, (*Y*) becomes inhibiting, that is to say, it behaves like an auxiliary source form—or like a preprogram that modifies the flow of the pregnance from (*X*) towards the source by deviating it towards an auxiliary well (*Y*) (cf. Le Ny's book given in note 6, pp.126–127).

(14) Alarm cries that differ according to the terrestrial or aerial nature of the predator are to be found in gregarious birds and in primates. For the location of food, the dance of bees (von Frisch) is classic. Vervet monkeys in East Africa have three different calls for three different types of predators, each evoking a different response that is appropriate to the situation (Struhsaker, 1968) and two warning calls of squirrel monkeys are specific to aerial or ground predators (Winter, Ploog and Latta, 1966)". Extract from *"Primate Communication," Neurosciences Research Program Bulletin*, 7, 5, November 1969, p. 443. According to M. Brémond, who directs an ethology laboratory in Nogent-le-Roi, many Passeriformes have a system of two distinct alarm calls, one that

creates a state of alert, announcing *the* presence of a distant predator, and the *other* to warn of an immediate danger from a predator that is identified and close at hand." Information kindly contributed by M.P. Buser, University of Paris VI.

(15) We are reminded of hysteria, which was, in Charcot's time, a phenomenon of collective pathology with no underlying biological root.

CHAPTER 2

LANGUAGE

A. From animal to man

We have seen that, in animals, a pregnance tends to spread from form to form. If there were nothing to hinder this propagation, we would very soon reach the catastrophic state of a predator for which any external form is prey. But in fact corrective mechanisms come into play quite early: unless an accidental association between forms is reinforced by repetition it becomes weaker and weaker and eventually disappears. Besides, animals are subject to only a few great regulative pregnances—fear, hunger, sexual desire. And although these pregnances have large propagative capacities, the associations thus created are themselves labile and reversible.

Man, on the contrary, can be invaded by a great number of pregnances: one might say that there is a pregnance attached to every one of his concepts, the propagative capacity of which is, however, strictly controlled. For it is this set of controls over the concatenation of symbols which sanctions the semantic acceptability of an expression: if X and Y are two concepts, the genitive X of Y makes sense (in a usual context) *if and only if the pregnance of Y can invest a generic reference of X*. For example, if Y is an organized form and if X is a necessary "feature" of Y, the genitive X of Y makes sense. There is a great difference, then, between animal communication systems and human language. How do we imagine this transition? Was it continuous or, on the contrary, broken, "catastrophic"? Naturally we can only speculate in an area where no verification seems possible; research on the origins of language has notoriously bad press! Nevertheless we may at least invoke here the traditional law of recapitulation: *ontogeny recapitulates phylogeny*.

B. Ontogeny of a child's acquisition of language

At the start, a new-born babe is completely imbued with the pregnance associated with its mother's body. An alimentary pregnance if the child is breast-fed, but one that also comes, without a doubt, from something of the mother's individuating pregnance focused upon the part that constitutes the foetus. This pregnance spreads rapidly and subjectively to parts of the mother's body (breast, face). (Ever since Spitz (1) we have known how the shape of a face can catch the eye of a baby just a few days old.) Then "transitional" objects appear (Winnicott (2)), like the other people who feed and look after it. There is also the pregnance attached to the baby's own body, which becomes autonomous if the organic coenasthesis is linked up with the external image of the body (mirror stage) (3). Outside objects acquire autonomy in so far as they can be objects of some action. We are witnessing a ramification of the mother's original pregnance exfoliating into a great number of beings and objects. At the same time the child hears words spoken by its parents and minders. By the process of *deixis*, the mother emits a quantum of her pregnance which goes to invest the object indicated (through contact with or visual prolongation of the pointing finger). At the same time she utters the corresponding word, and the pregnance belonging to the object is soon stabilized by coupling with the auditive sign. The word heard acts as a tunnel effect for this individuating pregnance of the object. The possibility the child has of causing the object to appear by saying the word reinforces the autonomy of this pregnance which eventually dissociates itself completely from that of the mother.

In adult language, *deixis* is observed to be a ritualization of this process. The speaker, in making the ostensive gesture, emits a transitory pregnance which invests the object shown and, conveyed by the designating word, ends by invading the hearer's psychism. Indeed, towards eight or nine months, when this process is implanted in the child, he will himself ask his mother the name of an object as he points to it. We know there is a critical period (between one and three years old) when an infant must be talked to, or it will be condemned to profound mental disability. For children so deprived ("wolf children" as they are called) (4), dissociations from maternal pregnance have not been stabilized and so autonomous pregnances have not been set in place. As a result the psychism remains dominated by a small number of biological pregnances of the animal type. During this sensitive period the potential well attached to the maternal pregnance flattens out and subdivides; it is a period of lability that is, without a doubt, genetically programmed (the psychic

equivalent of the axial mesoderm explosion leading to the formation of the vertebral axis). It may well be that animals also undergo a similar period of pregnance lability. Recent attempts at teaching primates a language seem, even if their interpretation is controversial, to demonstrate the existence of such a period in the life of the juvenile primate. But the naming of salient forms is just one aspect of language. Even more important is the syntactical pattern permitting the description of processes.

On the subject of man's acquisition of language, it is classic to mention the two-term *pivot-topic* sentence (5) of the type: "Carry Daddy" or "Daddy gone". It would be most interesting to analyze the semantic content of pivot terms. The four main types of singularity referred to in Chapter 3, section B, as organizers of biological morphogenesis, namely: beginning ⊢—, end—⊣, ramification —≺ and confluence ≻—, would certainly be shown to symbolize the content of these pivots in an adequate way. A confluence, for example, will first be expressed by a preposition like "with" ("*chez*" in French) before being expressed by a specific "divalent" verb, to use Tesnière's terminology. Only at a later stage do we learn to master the verb and, concomitantly, the genitive (preposition "of"). I shall not here reiterate the typology, proposed in *SSM* (6), of "archetypal" space-time processes which can be described by a single verb. I believe that my list of sixteen archetypal morphologies should be extended to include some verbs of a static character, like "contain" and "surround", expressing the fact that one entity "bounds" another and stops it from spreading outwards, and also perhaps such "negative" words as "pierce" and "drill". Further on, we shall discuss the semantic structure of the verb in general. As regards language ontogeny in the child, I would tend to believe that verbs which describe complex semantics implying the transfer of an invisible pregnance from subject to object are mastered at a later stage than verbs with an immediate "salient" meaning, like "fall" and "break". (Although it is true that essential biological pregnances such as "life" must appear fairly early. "Kill" is also probably acquired relatively quickly.)

C. Phylogeny

Let us now move on from ontogeny to phylogeny. If we impute, as we have just done, the essential task of language acquisition to parental *deixis*, we find ourselves wondering what "parents" could possibly have taught the language we use to our primeval ancestors, the prehominid primates. There is no shortage of teacher-gods in our mythologies, some of them, like Prometheus, cruelly chastised. I would be rather tempted to

believe that natural phenomena include ramifying forms which represent a kind of "natural *deixis*". Lightning—one of Zeus' major attributes—is a typical example of these ramifying forms, that will later give rise to Tesnière's zero-valent verbs (7). Biological pregnances have turned little by little into objective pregnances, physical in modern terms. Light, for instance, is a pregnance that has its own source forms (light sources), and that, when emitted by a source, transforms the objects on which it falls into secondary sources (it lights them up). Heat is a pregnance emitted by fire which invests all the bodies it warms. The mechanisms of propagation and investment of subjective pregnances—which act objectively on living beings—have been projected by empathy onto things.

The most surprising thing is that this process, *a priori* arbitrary, should have turned out to be such an amazing success with regard both to intelligibility and to its efficient action on the world. The discrete decomposition of naturally continuous processes into isolated facts is not just an illusion of the mind; the distinction between salience and pregnance is fundamental, even if sometimes it tends to be blurred: spreading and ramifying objects such as smoke from a fire, or chemical diffusions (odors), are pregnances which sometimes have a salient aspect; the phase transitions of matter, from salient solid to purely pregnant gas, provide an example of the modification of bodies which can be interpreted as due to conflicts between local pregnances (even in science: look at Van der Waals' model for liquid-gas transition) (8). (The form of a solid is a "figurative effect" of its "individuating pregnance" and at the same time its definition!) So it is easy to understand why exceptional natural forms (*lusus naturae*), such as rocks resembling human faces, were endowed with a pregnance that is half religious, half magic, an undifferentiated pregnance in which Durkheim saw the origin of the modern notion of energy (9). (On this subject, see Cassirer's theory of symbolic forms (10).) It is striking to note that even the most pregnantial of physical theories, quantum field theory, has rediscovered, with the confinement of quarks responsible for the stability of atomic nuclei, something tantamount to a localization of a salient nature. In the *Nouvel Esprit Scientifique* (11) Bachelard comments ironically on the "prescientific" models put forward by early eighteenth century physicists in order to explain the properties of the magnet (which bears in French the suggestive name of "aimant"), namely, the presence in a magnet of a sponge-like structure where iron is mingled with an attracting fluid. It is plain here that the scientific mind was trying to visualize materially the pregnance that is a magnetic field by blending it intimately with the salience of matter.

D. Syntactical structures

In human as in animal action, there is as it were a "thickening" of abrupt (catastrophic) transition between the virtual investment of a subject by a pregnance and the "satisfaction" resulting from the act. There can scarcely be any doubt that the essential function of that part of speech we call "verb" is to symbolize this transition. Thus the typical transitive sentence (The cat eats the mouse) describes a process that can be formalized as follows:

1. The subject is assailed by a virtual pregnance (desire with no immediate object).

2. The object appears. The subject then emits in its direction a "local" pregnance which reaches and invests the object (unless there is failure!).

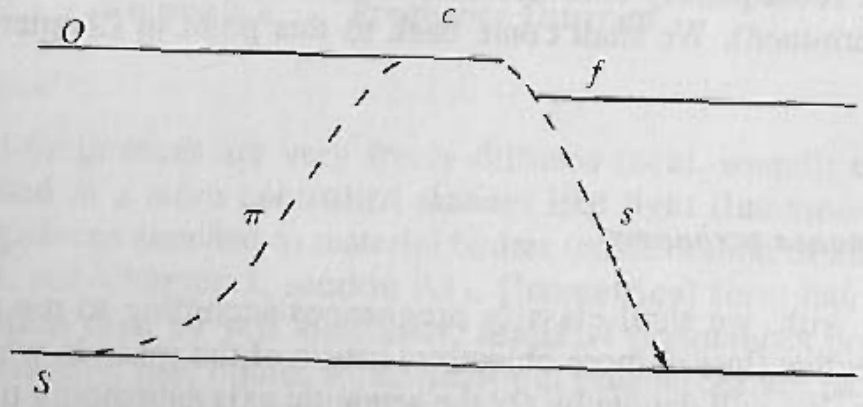
3. Following this investment there is conflict in the state of the object between its own individuating pregnance and that received from the subject.

4. The result of the conflict—seen as a transformation of the state of the object—is implicit in the meaning of the verb expressing, in particular, the subject's "satisfaction" (Figure 2.1).

When the "verb" is used to describe the processes of inanimate nature, part of this process tends to disappear: everything, in particular, that deals with the intentionality of the subject and its satisfaction. But the initial part of the process, its topology, subsists as a plan of interaction. No one familiar with Feynman's graphs (12) will contradict me here. Immense problems are of course raised by the "objective" definition of what, in linguistic terms, is known as a "fact". There is the fact in the process of being accomplished, and there is the result of the action which is also considered to be a fact ("perfect" in classical grammar). I would be inclined to think that syntactical structures probably have their origin somewhere in social necessity. As soon as the leadership of a human (or pre-human) group was taken over by one individual, a "monarch" in the etymological sense, it became necessary for him to occupy a more or less central position in the group and he was no longer able to keep watch over the entire surroundings. The "sentries" placed on the outskirts were then required to report back to the leader and describe, precisely enough for practical purposes, any new fact of importance to the group (like the presence of potential prey or of an enemy in such and such a part of the territory). Thus the localization of external facts appeared as an essential part of social communication. Now localization, for salient forms, is the ultimate end of naming, in effect the containing relationship (metonymy): X is in Y is a basic form of investment (the localizing pregnance of Y invests X). When X is invested with a ubiquitous biological quality (favorable or hostile), then so is Y.

From there on, a divalent syntactical structure became absolutely necessary if a conflict between two outside actants was to be reported. Trivalent structures appear only when the pregnance between subject and recipient is itself conveyed (incarnate) *in a salient* "messenger" form. Whence the ambiguous character of a gift, the means by which the donor can impose his pregnance on the receiver (cf. Marcel Mauss and the German *Gift*). It may seem like an over-simplification to see the origins of language in the informational necessities of "military" intelligence. But it would not be the only time that the requirements of the art of war have contributed to the progress of humanity. Of course, what we said in Chapter 1 about having to modulate one's perception of an enemy sign by an affix of the "genitive" type points exactly in the same direction.

Alongside this wholly pragmatic necessity of transmitting an often vital piece of information, one might consider a more subtle interpretation. The description of syntactical structures I proposed in *SSM* still answers to the following definition: the signification of a verb can be



π pregnance emitted by the subject
c conflict between π and the individuating pregnance of the object
f figurative effect
s benefit to the subject resulting from the transformation *f* of the object
S subject
O object

Figure 2.1 Schema of the complete transitive sentence SVO

represented in a suitable control space, as a class of trajectories transversal to a catastrophe hypersurface, describing the abrupt transition from a stable state 1 to another stable state 2. This hypersurface may be seen as a "shock wave" between the two states. Now the structure of a shock wave (in the theory of the "soliton" for example) is characterized by a path in an auxiliary differential model between a singular point a representing state 1 and a singular point b representing state 2 (15). In general the salient discontinuity carrying essential information—Aristotle's *logos apophanticos*—has an internal structure of the trajectory landscape type (a graph), of stable or unstable cells coming from singular points. From the organizing center of the whole structure, we define a sequence of "small" translations which make this path transversal to the catastrophe locus.

An explicit description of this dynamic will enable us to verify the principle of Thirdness proposed by Charles S. Peirce. The primary stage affirms the impact on the mind of a stimulus of outside origin P; the secondary stage concerns verbal localization in the semantic field where the conflict is taking place; finally the ternary stage is the saturation of verbal knot valences by actants which have to be located (or identified). Thus the enunciation of a sentence is similar to embryological development, going from the abstract to the concrete. Here we start with the predicative knot in its pure state, localized in verbal form in its semantic field, and subsequently unfolded into actants which will later be localized (determined). We shall come back to this point in Chapter 8, section E.

E. Pregnance taxonomy

To begin with, we shall classify pregnances according to the more or less subjective (less or more objective) nature of the space in which they propagate. We will denote by Ox the semantic axis subtending the opposition objective-subjective. At the objective extremity ($x < 0$), the semantic space is none other than the usual Euclidean space; at the subjective extremity ($x > 0$) we have the axis spanning the fundamental biological oppositions, such as (Life, Death), (Good, Bad). Then come the auxiliary pregnances of linguistic activity, such as the deictic pregnance of the object indicated. Between the two, we have semantic fields such as color impressions, deriving at the same time from spatial extent, from the physics of light and from the physiological filter of color presentation, the spaces of material qualities (heavy, fluid...) and moral qualities (rich, wity...). A second axis Oy measures the character more or less free, less or more controlled, of pregnance propagation. Certain

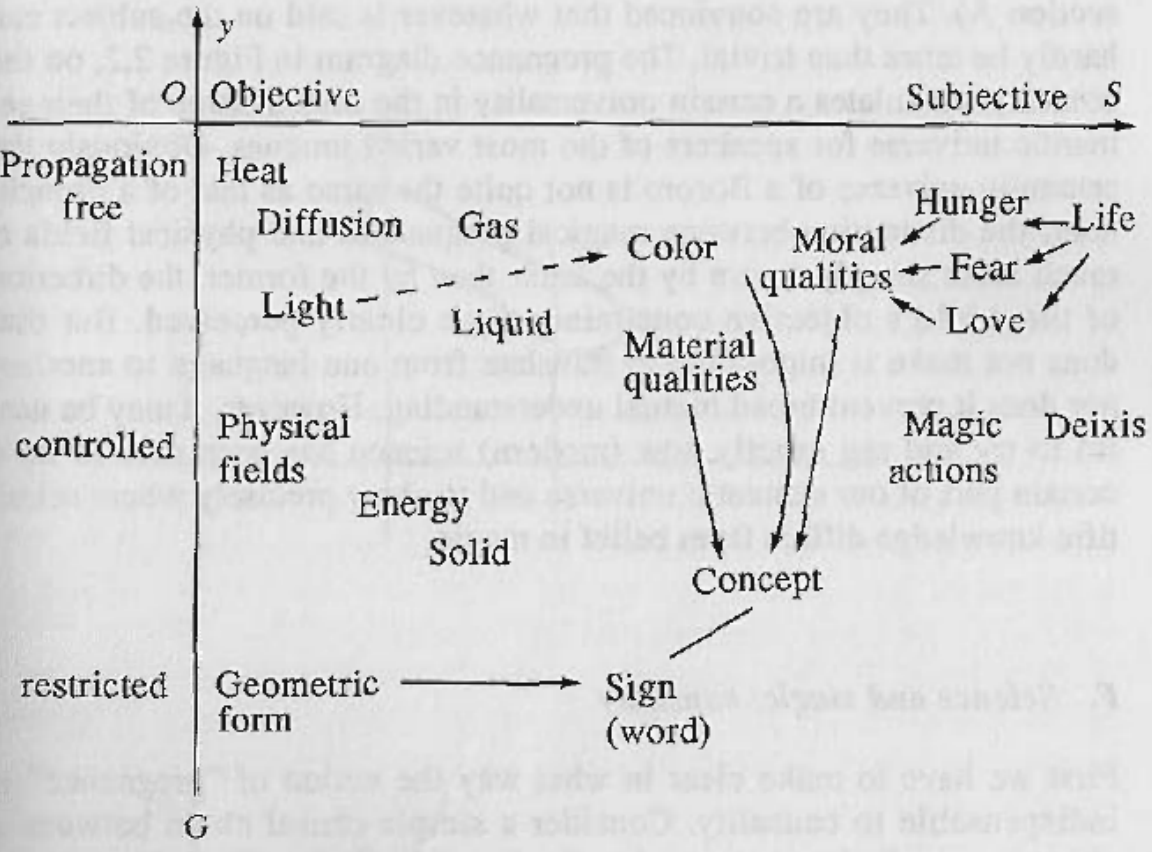


Figure 2.2 Pregnance Diagram

physical pregnances are very freely diffused (heat, sound); others are propagated in a more controlled manner like light (luminous rays) or like pregnances attached to material bodies (conservation of kinetic momentum, see Chapter 3, section A1). Geometrical form has no other propagation than by self similarity. Material pregnances present the same hierarchy: gas, liquid, solid. Sensorial pregnances are likewise arranged in a similar hierarchy (smell less controlled than color). Conceptual pregnances are strictly controlled. This brings us to the general table of Figure 2.2.

As the linguist H. Seiler observed (16), adjectives qualifying an actant are placed (in certain languages) in a fixed order. Thus in the German syntagma we have: *Diese erwähnten zehn schönen roten Holzkugeln*, where pregnance order follows roughly the diagonal of the table, going from the vertex *S*: free-subjective to the vertex *G*: fixed-objective.

Of course all these considerations have only a limited impact on linguistics proper. What interests the linguist is not what is common to languages, but what brings about their differentiation. Specialists in linguistics often evince considerable suspicion when it comes to the

question of universals (we will come back to this point in Chapter 8, section A). They are convinced that whatever is said on the subject can hardly be more than trivial. The pregnance diagram in Figure 2.2, on the contrary, postulates a certain universality in the organization of their semantic universe for speakers of the most varied tongues. Obviously the semantic universe of a Bororo is not quite the same as that of a Frenchman; the distinction between magical pregnances and physical fields is much more sharply drawn by the latter than by the former, the direction of the world's objective constraints more clearly perceived. But that does not make it impossible to translate from one language to another, nor does it prevent broad mutual understanding. However, it may be useful to try and see exactly how (modern) science has been able to fix a certain part of our semantic universe and to show precisely where scientific knowledge differs from belief in magic.

F. Science and magic: causality

First we have to make clear in what way the notion of "pregnance" is indispensable to causality. Consider a simple causal chain between a phenomenon C, the cause, and a phenomenon E, the effect. Place these phenomena as forms in their space-time setting (x,t). C and E are salient forms. There are two possible cases. Either:

1. C and E are two sections in time $t = t_0$, $t + t_1$ of the same salient spatio-temporal form F (Figure 2.3a). In this case, causality can be reduced to the trivial form of the object's permanence ("All beings tend to persevere in their being", wrote Spinoza (17), in a more general context), or:

2. C and E are separated in space-time by a gap. The causality which gave rise to E, out of C, is *action from a distance*. The mind will always try to bridge this gap by restoring some morphological continuity between cause and effect (Figure 2.3b). It will be supposed that the phenomenon C has given out invisible "influences", propagated through space-time to a domain where they have created the effect E or contributed to its creation. These influences could be "particles", salient forms too small to be detected, or "waves" of rarefied ether filling up space, or actions about whose nature no conjectures can be made (like magical actions). Such non-localized entities, alike only in the effects they have on salient forms, are typically objective pregnances.

EXAMPLE. When a magnet is moved in the vicinity of a compass, the needle tends to turn towards the magnet; a pregnantial and ubiquitous being will be introduced—the magnetic field—depending on, and

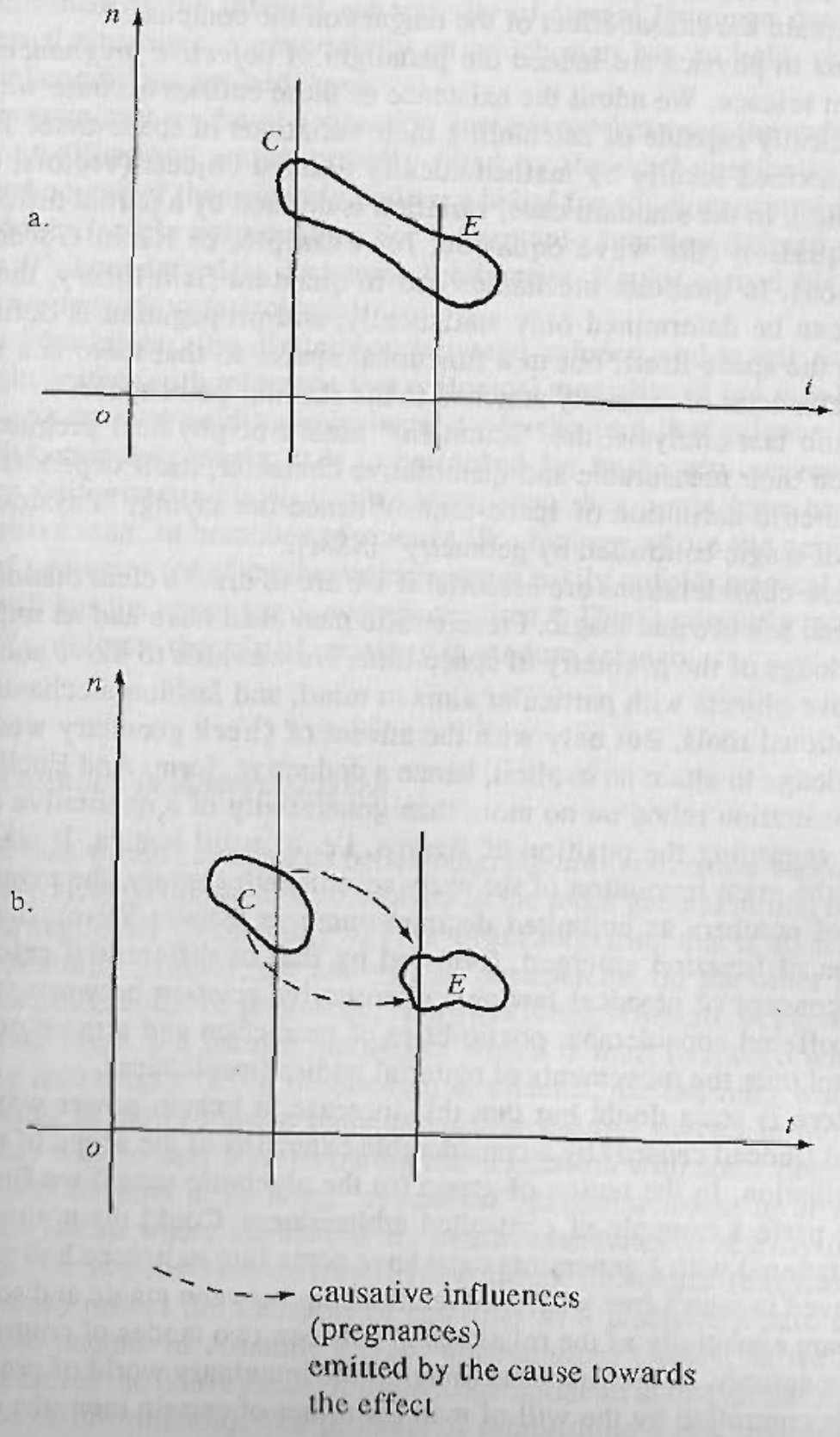

a.
n
C
E
o
t
b.
n
C
E
o
t
causative influences
(pregnances)
emitted by the cause towards
the effect

Figure 2.3

acting on, both the needle and the magnet. The variations of this field will explain the causal effect of the magnet on the compass. *

Fields in physics are indeed the paradigm of *objective pregnances* in modern science. We admit the existence of these entities because we are theoretically capable of calculating their variations in space-time. They are described locally by mathematically defined objects (vectors, tensors, etc.). In the standard case, variation is defined by a partial differential equation (the wave equation, for example, or Klein-Gordon's equation). In quantum mechanics and in quantum field theory, the effects can be determined only statistically, and propagation is defined, not in the space itself, but in a functional space, so that there is a nonlocal character of causality attached to the starting-point space.

In the last analysis, the "scientific" nature of physical pregnances rests on their measurable and quantitative character, itself dependent on a geometric definition of space-time. Whence the saying, "Physics is a form of magic controlled by geometry" [*SSM*].

These considerations are essential if we are to draw a clear distinction between science and magic. Prescientific man must have had an implicit knowledge of the geometry of space-time. He was able to move about in it, move objects with particular aims in mind, and fashion mechanically operational tools. But only with the advent of Greek geometry was this knowledge to attain an explicit, hence a deductive, form. And Euclidean demonstration relied on no more than generativity of a qualitative character regarding the position of figures, i.e. of solid bodies. It was not until the great revolution of the early seventeenth century, the invention of real numbers as unlimited decimal numbers (Stevin-Viète), that the notion of function emerged, followed by that of differential calculus. The concept of physical law as a quantitative relation between values then offered considerable possibilities of prediction and a more precise control over the movements of material bodies (mechanics).

There is scant doubt but that this increase in human power was preceded (indeed caused) by a considerable extension of the scope of man's imagination. In the notion of group (in the algebraic sense) we find the most perfect example of controlled arbitrariness. Could the notion of a free monoid with k generators even have come into existence had we not believed in man's free will? The relationship between magic and science appears essentially as the relationship between two modes of controlling the imaginary. In the first case (magic), the imaginary world of pregnances is controlled by the will of man (or rather of certain men, the magi-

* Physical theory tells us that there is perfect reciprocity here: in moving the needle we act on the magnet, although the effect is more difficult to observe because of the disproportion in mass.

cians, experts in efficient practices); in the second (science), control is determined by the internal generativity of formal language describing external situations, a generativity on which man has no hold, once the initial conditions are laid down.

In astrology we have a situation somewhere between the two. Here human situations are supposedly ruled by the mathematically determined course of the heavenly bodies, a belief for which geocentrism was no doubt largely responsible. For a harmonic function defined on the disk $\mathbf{D}^2$, boundary data determine the interior. Kepler earned his living as a *mathematicus* (astrologer).

In conclusion, the distinction between science and magic is to be sought neither with reference to a prelogical mentality (*à la* Lévy-Bruhl) nor—as many would naively have it—in the fact that science works much better than magic. It is to be looked for in the way we represent space with constraints so much greater than they could have been for primitive man. In branches of science like biology where the generativity of geometry (or of mathematics) cannot easily unfold, magical thinking still has the upper hand, even in our time.* This is currently raising a set of problems: the role of causality in modern science.

G. *Causality in modern Science*

Positivists would have had us believe that the notion of cause was only a metaphysical residuum to be dissolved in the more general notion of scientific regularity ("nomology"). This meant forgetting that if all science is necessarily general, the analysis of phenomena, on the other hand, whether theoretical or pragmatic, is always *local*. After all, in the notion of cause there is a locality constraint which is hard to forego without falling into magic. (Even in quantum mechanics, the causality which is non-local in the (q_i) space remains local in the (p_i) space.) In biology, the only way to deal with physiological regulation with some degree of precision consists in building "cybernetic" diagrams made up of interacting systems where the arrows are in alternate states of activity (excitation) or repose (inhibition). Now these concepts (excitation, inhibition) reflect the transport of causality in a practically pure state, after the manner of Aristotle's *logos apophanticos* (which, as we have said, ensures the conveyance of knowledge about an actual situation, i.e. a piece of information). The problem of establishing a link between cybernetic formalism and the differential formalism of dynamics ought to

* I am alluding here to the use of concepts such as genetic information and the demiurgic role of enzymes in biochemistry.

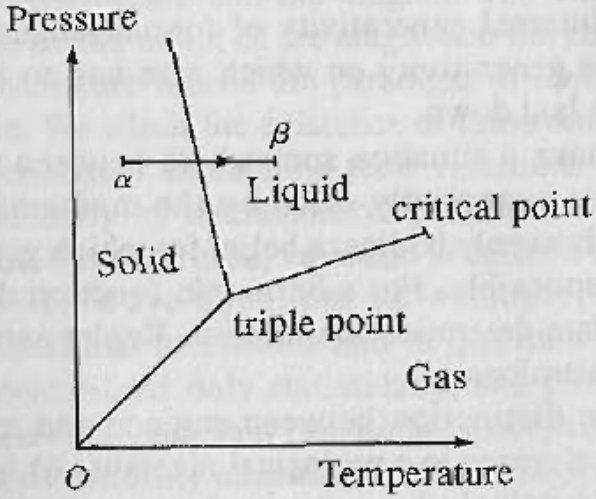


Figure 2.4 Typical phase diagram with $\overrightarrow{\alpha\beta}$ as fusion path

be, in my opinion, the essential task of "natural philosophy". One cannot do without causality when one is trying to find out what causes (or prohibits) a phenomenon.

But causality is hard to express in terms of dynamic formalism, because dynamics deal precisely only with isolated systems, whereas the essence of the cybernetic diagram is to deal with the *actions* of one system on another (as Mario Bunge (18) very rightly notes in the axiomatics of his *Exact Philosophy*). If we want to move towards a synthesis, I believe we need to look in the direction of catastrophe theory formalism. We have seen that the transitive sentence can in certain cases be represented by a class of trajectories transversal to a catastrophe hypersurface ("The cat eats the mouse"). In the same way, a sentence like

"Heat melts ice"

exemplifying efficient causality, will be represented by the path $\overrightarrow{\alpha\beta}$ transversal to the solid-liquid separatrix of the water phase diagram (Figure 2.4).

In Chapters 3, 4, and 5, I will develop a formalism aiming to describe both the embryology and the comparative anatomy of the different *phyla* of the animal kingdom; in all these cases I attempt to explain both organogenesis and physiology, starting from a unique dynamical structure (originating in the predation loop) which subsequently becomes more and more complicated, so as to account for breaks in causality brought

about by catastrophic discontinuities in the structure of the predator-prey system.

The biology theorist Robert Rosen proposed in a recent work(19) an interpretation of Laplacian determinism in terms of Aristotelian causality: the differential law (M,X) would depend on formal causality and the initial condition on material causality. It is a fact that it is much easier to displace a solid body than to create it *ex nihilo*. Efficient causality appears only in the origin of the formal expression of the differential system. Newtonian dynamics, for instance, may be considered as an intelligible ontology, the salient entities of which are the material points (or solids, which are rigid systems of material points) and the pregnances of which are kinetic momentum $J = m\vec{V}$ and force F. When a force F invests a material point of mass m, it creates there the figurative effect defined by the formula

$$F = \frac{dJ}{dt} .$$

The law of gravitation can be interpreted as follows: each material point emits a pregnance defined by a force F whose intensity at P decreases in inverse ratio to the surface area of the sphere of radius (OP) (as if the flow of pregnance were conserved). Thus, if it is to be explained, formal causality requires an ontology of salient forms and pregnances interacting according to a probable mode that is mathematically determined.

A description of major scientific theories from the salience-pregnance angle can be found in my article "Le problème des ontologies régionales en Science" (20), to which I invite the reader to refer for a more complete list of examples.

II. Scientific progress seen as objectivation of a subjective pregnance

The clearest example of efficient causality is that of *a tergo* causality (kick in the behind), in other words, an impact. Now when you analyze the elastic shock of two balls A and B along an axis as a function of their respective speeds V_1, V_2, and you describe it linguistically as it appears in a mobile frame of reference of constant speed u on this axis, you find that the Ou axis is practically decomposed into five distinct regions according to the phenomenological nature of the shock (A and B bump into each other, A hits B, B hits A... see Chapter 3, section A1). When a moving ball strikes a fixed ball, it is always the mobile element that is the grammatical subject and the fixed element that is the object. In collision the subject imparts all (or some) of its kinetic momentum to the object. Thus the kinetic momentum is the subjective pregnance, emanating from the subject and transmitted to the object in the course of impact.

We know that in modern terms the conservation of kinetic momentum is a formal consequence of invariance according to Galilean symmetry. In itself the phenomenon has no irreversibility. The apparent irreversibility is due to the choice of reference linked to the observer. How, starting from an empirical observation of collisions, did we end up with the notion of kinetic momentum? I believe that it came about through a process of empathy: when the observer watches a collision, he identifies himself either with the subject or with the object. In the first case he feels satisfied at having removed an obstacle; in the second he feels the pain of being hit.

Note that if it is directed towards the observer's own body, the kinetic momentum of a mobile material body is endowed with biological pregnance. Anticipating the path of the object, he will try to move out of the way. This process of empathy can be symbolized by the proportion (Aristotelian, not mathematical)

$$\frac{\text{Objective pregnance}}{\textit{Gedankenexperiment}} = \frac{\text{Subjective pregnance}}{\text{Real affective experience}}$$

Thus the observer's capability of *putting himself in the place of things* could well be at the origin of any important scientific progress.

I. Determinism and contingency

One point should be made clear: the salience-pregnance model does not aim to predict phenomena. When a subject proposes to act on an object, the success of the action is never certain *a priori*. When a pregnance attains a salient form, we never know whether it will succeed in investing this form, or what figurative effects will result if it does so. All this means that the description of the universe in terms of this formalism is not stable but constantly subject to revision. It is the function of Aristotle's *logos apophanticos* to keep the mind ever aware of changes in the state of salient entities, of pregnance invasions and of their effects.

The origin and the more or less permanent flow of this *logos* might be problematic. I mean—and this precious remark I owe to a Swedish friend, Pehr Sällström—that salience can be explained only by the presence of a universal source of "luminous" pregnance. A salient form has to be lit up before it can be seen. This situation explains the paradox in verbs of sensation: when I look at a thing *C*, that thing is the grammatical object of the verb "to look at". So I emit a "subjective" pregnance

towards *C* which invades it. But in order to see *C*, my eye has to receive the photons *it* emits. The physical objective pregnance (light) and the subjective linguistic pregnance are here moving in opposite directions (cf. Aristotle's *Nous pathètikos* and *Nous poiètikos*, described in the treatise *De Anima*, Chapter 3, section 5).

Some may wonder, in this connection, whether darkness should be looked on as a pregnance; indeed it should, for the propagative virtues of darkness are evident. But light and darkness are antagonistic pregnances whose conflict is controlled by optics. We see that science here is doing its best to get rid, as thoroughly as possible, of the fundamental qualitative indetermination of the model.

J. Pregnances in cultural life: paradigms and ideologies

All ideologies, that is to say all systems of belief that are socially (though *not* necessarily intellectually) coherent, are built in the beginning upon a small number of principles from which all the rest follows; these "principles", the conceptual nature of which can vary considerably, play the role of "source forms" for a pregnance which invests all those who put their faith in the ideology. Generally they are vague concepts whose propagative power comes precisely from their fuzzy and ill-defined character. They serve as passwords: the follower who invokes them at every turn (and even out of turn) is demonstrating his allegiance to an ideology. We can tell, by his use of these flag words, to what particular ideology a person subscribes (*). The same analysis holds for scientific paradigms in Kuhn's meaning of the word (21). A paradigm is born following some initial achievements in a domain of experience *D*, its "nuclear" domain. But the paradigm is forever living above its means; it proposes to explain more than it could reasonably hope to do. The signification of concepts successfully used in the nuclear domain is subsequently extended, stretched in a way that is both ambitious and imprecise. The supporters of the paradigm will then invoke the flag words in the sort of conditions we have described. Yet such abusive extensions are not arbitrary. The entire Levi-Straussian structuralism is hinged on the formal constraints regulating mythological systems. In the same way, constraints are implicit in today's paradigms. No doubt, as the expression of underlying dynamic archetypes, these constraints reinforce the system's power of evidence and cohesion.

* Note that this is in no way incompatible with the sincerity of the statement; the intellectual dishonesty lies in the system itself—not in the mind which may simply be victim of the system.

A fascinating (though probably difficult) subject of research would be the description in terms of "pregnance effects and conflicts" of the way mentalities evolve in a society and of how the principal components of the *Zeitgeist* intervene all the time. In this respect the phenomena of fashion arising out of the "mimetic desire" dear to René Girard(22) may well be interpreted in terms of pregnance. The act of appropriating a desired object imbues this object with a pregnance, the same pregnance as that which is associated with the act by which "satisfaction" is obtained. Small wonder then that this pregnance should be propagated by imitation, through the mere sight of "superior" individuals in whom it is manifest. In a sense, the pleasure derived from looking forward to a satisfaction can surpass that obtained from the satisfaction itself. This helps to explain how the most blatantly erring beliefs and doctrines should have been able to seduce societies century after century (their pragmatic failure in real terms having allowed them to escape the indifference that goes with satiety as well as the ordeal of actual existence).

NOTES AND REFERENCES

(1) After Mélanie Klein, psychoanalysis put a great deal of emphasis on the primal identification of the new-born infant with its mother's body. A more scientific approach is that of René A. Spitz in *De la naissance à la parole, la première année de la vie*, in collaboration with W. Godfrey Cobliner (translated by Liliane Cobliner), third edition, PUF, Paris, 1971.

(2) Winnicott, Donald W., "Objets transitionnels et phénomènes transitionels", *De la pédiatrie à la psychoanalyse*, Payot, 1969, p. 109–125

(3) "Le stade du miroir comme formateur de la fonction du Je, telles qu'elle nous est révélée dans l'expérience psychanalytique", in Jacques Lacan, *Ecrits*, le Seuil, Paris, 1966.

(4) On children deprived of language as a result of having no human contact at a critical period, see Lucien Matson, *Les enfants sauvages*, Maison Générale d'Editions, Paris 1964.

(5) Infant language. **The two word sentence.** The *pivot-topic* distinction appears to be due to Braine (1963). A rather short analysis of this childish grammar is to be found in E. Lenneberg's *Biological Foundations of Language*, John Wiley, New York, 1967. See also F. Francois, *La syntaxe de l'enfant avant cinq ans*, Larousse, Paris, 1975, and Wildgen and Mottron, *Dynamische Sprachtheorie*, ed. Bockmeyer, Bochum, 1988, Chapter 4.

(6) R. Thom, *Modèles Mathématiques de la Morphogénèse*, Christian Bourgois, Paris, 1973, p. 213.

(7) L. Tesnière, *Eléments de syntaxe structurale*, Klincksieck, Paris, 1966.

(8) **Van der Waals model.** Here we have a fluid whose state equation is $(p + aV^{-2})(V - b) = RT$. The application of Landau's theory, where the liquid-gas separatrix is given by Maxwell's convention, leads to a cusp catastrophe.

(9) Durkheim opposed Lévy-Bruhl's theory on primitive mentality, arguing the existence of concepts uniting physical "energy" and what is sociologically "sacred". See *infra*, section E.

"La force impersonnelle dont le totem est le symbole se retrouve chez les Mélanésiens sous le nom de *mana*, une notion qui est l'équivalent exact du *Waken* des Sioux, de l'*orenda* iroquois" (in "Les Forces élémentaires de la vie religieuse"). Extract from the article "Durkheim Emile" of the *Dictionnaire Critique de la sociologie*, by R. Boudon and F. Bourricand, PUF, Paris, 1982.

(10) Cassirer, Ernst, *Theorie des symbolischen Formen*, three volumes (1923–29). English translation: *The Philosophy of Symbolic Forms*, Yale University Press, New Haven, 1953.

(11) G. Bachelard, *Le nouvel esprit scientifique*, 1934, reedition PUF, 1946.

(12) **Feynman graphs.** Richard Feynman, *Lectures on Physics*, Addison-Wesley, three volumes, 1963–65. French translation: *Le cours de physique de Feynman*, five volumes, InterEditions, Paris, 1983.

(13) Marcel Mauss, "Essai sur le don", in *Sociologie et Anthropologie*, PUF, Paris, 1950.

(14) This vision of the origins of syntactic structure has been objected to on the grounds that the military organization of human societies came after urbanization and is therefore relatively recent (20,000 years at the most?). That would of course be a bit short to account for the syntactic structures of grammar; a more general motivation therefore seems necessary and is not at all improbable, for the localization requirement is not exclusively military.

(15) In the theory of the one-dimensional soliton on the axis OX, we consider a propagative process defined by the partial differential equation

$$u_t = f(u, u_x) \qquad \text{(E)}$$

We look for a solution u of form $\varphi(x - vt)$, with v constant. We obtain for φ : $-v\varphi' = f'_u(\varphi, \varphi')$, that is an ordinary differential equation (E) depending on the parameter v.

A shock wave is a path connecting the stationary values of the field, two stationary solutions u_1, u_2 of (E_v). We then have to determine the value of v for which the two solutions u_1, u_2 are connected by a separatrix for the differential field defined by (E_v). In a sense we again find the smoothing theory described *infra* in Chapter 4 (a local externalization of internal variables).

(16) Hans Jakob Seiler, *Materials for the DFG International Conference on Language Universals*, Gunnersbach, 1976, AKOP, 25

(17) Spinoza, *Ethics*, part 3, proposition 6.

(18) Mario Bunge, *Exact Philosophy*, Reidel, 1973.

(19) Robert Rosen, *Theoretical Biology and Complexity, Three Essays on the natural Philosophy of Complex Systems*, Academic Press, 1985.

(20) René Thom, "Le problèm des ontologies régionales en Science", in *Philosophie et Culture, Actes du XVII^e Congrès International de Philosophie de Montréal*, 1983, Editions du Beffroi, Editions Montmorency, 1986.

(21) T.S. Kuhn, *The Structure of Scientific Revolutions*, Chicago University Press, 1962. French translation, *La structure des révolutions scientifiques*, Flammarion, Paris, 1983.

(22) René Girard, *Mensonge romantique et vérité romanesque*, Grasset, Paris, 1961.

CHAPTER 3

THE NOTION OF PREPROGRAM: BIOLOGICAL AND TECHNICAL MORPHOGENESES

A. General theory of interactions in an intelligible ontology

We have shown in Chapter 2 that our vision of the world is broken up into comparatively distinct disciplinary fields. A disciplinary region is specifically constituted only when some regional ontology, made up of *salient forms* and *pregnances,* has been associated with it. Let me remind the reader of this structure.

Salient forms are individuated forms in a substrate space which we shall, as a rule, consider to be Euclidean. *Pregnances* are propagative actions emanating from salient forms and *investing* them. Such investment causes transformations in the state of these forms which we call *figurative effects.* When trying to describe interactions taking place between these entities we have to consider the following four cases:

1. SALIENCE ⇔ SALIENCE. This is *collision.* Since our hypothesis does not include action at a distance, all we can consider here is collision, competition for space between two salient forms. The problem is to ascertain whether there are pregnances that intervene in the interaction. If there are, then they are conveyed *via* the surface of contact between the two forms.

In mechanics, we know how to deal with collision. In the purely theoretical situation of *elastic* collision, we know that the conservation of the kinetic momentum $\Sigma m_i v_i$ and of kinetic energy $\Sigma 1/2 m v_i^2$ is enough to determine the kinetic state resulting from collision. In situations closer to reality where plasticity and friction are involved the description we have is far from equally satisfying. We may, however, observe that, here again, kinetic momentum and kinetic energy can be considered as pre-

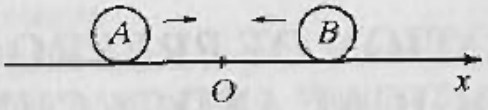


Figure 3.1 Collision of two equal balls

gnances (of, respectively, a vectorial and scalar character) which are transmitted by the moving body to the fixed one. Take the following easy mental experiment (1). Let A and B be two equal hard balls, sliding freely along the horizontal axis Ox and hitting each other elastically at O. An observer is connected on Ox to a Galilean frame of reference moving at a constant speed v with respect to the mass center taken as origin, $x = 0$ (Figure 3.1). He is asked to describe in words the phenomenon of collision. Let w denote the speed of the left-hand ball before collision, with $w > 0$ at $(x = -0)$, then we have

For	$v < -w$	ball A catches up with ball B
	$v = -w$	ball A hits ball B (immobile until then)
	$-w < v < 0$	ball A and ball B hit each other
	$v = 0$	
	$0 < v < w$	
	$v = w$	ball B hits ball A
	$v > w$	ball B catches up with ball A

In all these cases the ball that is immobile (or has low kinetic momentum) is the patient (grammatical object), the faster-moving ball is the agent (grammatical subject). This example is particularly significant because it brings out the interconnection between *objective pregnance* (kinetic momentum $m\vec{v}$) and *subjective pregnance* (the quality of agent or of patient). Note that the two forms in contact can exchange pregnances other than the purely mechanical ones we have mentioned. Such is the case in the example from Chapter 6, section G: "The mother warms her child"; here continuous contact results in an exchange of quantities of heat (a new type of pregnance); infection provides further examples of pregnance transmission through contact.

2. SALIENCE → PREGNANCE. THE NOTION OF PREPROGRAM. This is in reality the way one pregnance can act on another *via* a salient form. We shall go on to develop the theory of this type of interac-

tion, of considerable biological and technical importance, by introducing the notion of *preprogram.*

3. PREGNANCE → SALIENCE. Here we are talking about the *figurative effects* due to the investing of a salient form by a pregnance. A comprehensive theory has yet to be put together. The simplest case is where the investing pregnance is re-emitted by the invested form (as in microbial contagion for instance). Sometimes the pregnance may be re-emitted in a more intense form or, on the contrary, in a weaker one (light diffused by opaque objects). Sometimes the invested form undergoes a morphological transformation; it can even be purely and simply destroyed (as when your fist shatters a pane of glass); or it may re-emit a different pregnance. A general theory of such effects is one of the tasks facing semiophysics. Nevertheless, ontological autonomy does suggest a certain permanence in the pregnances involved (or in the appearance of degraded pregnances such as heat in thermodynamics, where heat is a degraded form of energy in comparison with kinetic or electromagnetic energy).

4. PREGNANCE ⇔ PREGNANCE. In so far as pregnances share the same substrate space, it might be interesting to know to what extent the presence of one pregnance can influence the propagation of another. In a conflict between individuating pregnances we again find the catastrophe model, with *collision* as the limit. Field theory in physics shows how difficult the problem is; the quantification of a field is attributed to the fact that it can be represented by salient forms, individuated more often than not, but the associated formalism is far from transparent! In a sense, the interactions associated with syntactical structures are also of the pregnance-pregnance type. This would be the case for "species" competing within a genus according to Aristotle's concept of motion as imparted by a "mover" to the "moved" (cf. Chapter 6, section G).

B. The notion of preprogram: an obstacle in the way of a flow

Now let us come back to the ways in which a salient form can act upon a pregnance. The salient form may allow itself to be invested, very briefly, before re-emitting the pregnance in a directional mode different from the mode of invasion. Or else it may "obstruct" the propagation of a pregnance from outside. We become aware of the existence of things in so far as we see and touch them. In both instances we are receiving pregnances re-emitted by an object. So there is a transformation brought about by an object on the flow of an ambient pregnance (light in the first case, the "kinetic momentum" of my hand in the second). These are particular cases of the principle of the obstacle as a source of ontology (2).

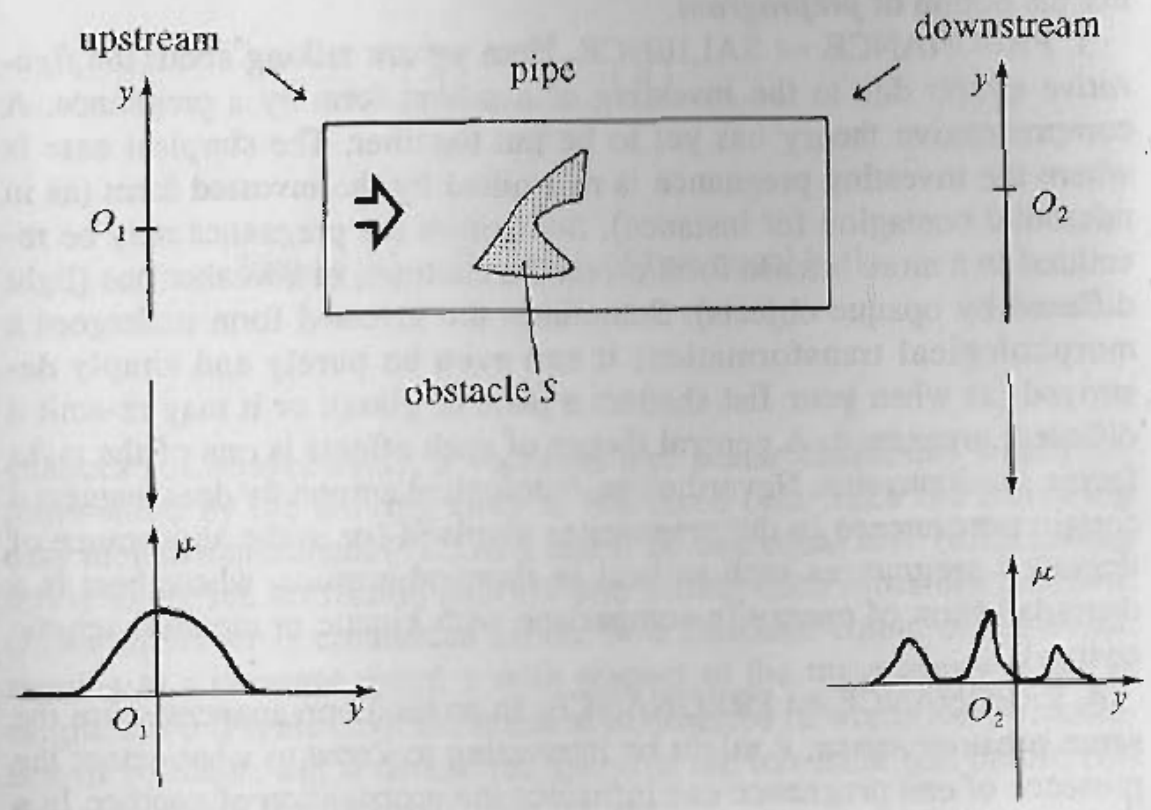


Figure 3.2

An important instance is that of a *mobile* salient form interacting with an external pregnance flow. Take the case where this flow is the current of a fluid inside a canalization. Upstream we will suppose the current in a section of the tube to have a density μ which is positive and zero on the boundary, like the bell-shaped function (Figure 3.2).

In this fluid we place a solid body S which can be moved according to position parameters q_i, $1 < i \leq 6$ forming a space Q. Downstream from the obstacle $S(q_i)$, the current will take on an asymptotic density defined by a density function $\mu\,(q_i,y)$, where y denotes some parametrization of a downstream section Y. Although there is no theorem in hydrodynamics which affirms that the downstream current should adopt an asymptotic regime, we shall assume that such an asymptotic regime defined by the function $\mu^+(q_i,y)$ does in fact exist, and, what is more, that this function $\mu^+(q_i,y)$, considered as a function $\tilde{\mu}$ of the (q_i) parameters, is a continuous map (in topology C^k, with k sufficiently large) of the space Q in the function space $\mathcal{L}(Y)$ of the smooth densities $\mu(y)$. If we are interested only in the "number" of currents due to the obstacle, that is to say, in the cardinal number of connected components of the downstream section Y

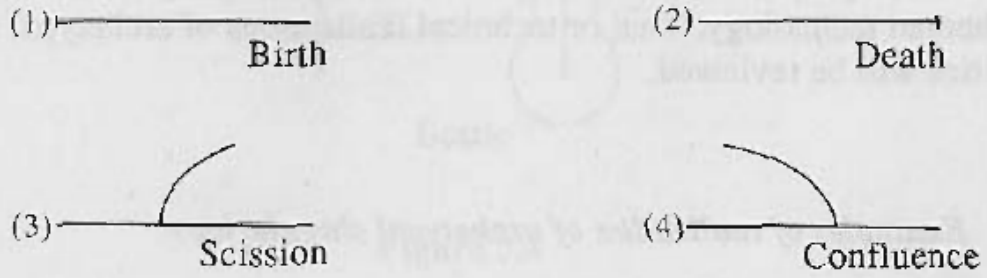


Figure 3.3

where μ is strictly positive, then for every path $q_i(u)$ in the space Q there will be a corresponding graph Γ that associates, with every value of $u \in 1 = [0,1]$, the discrete set of points defined by the centers of gravity in Y of each of the "currents" in the section.

One consequence of the hypothesis of continuity formulated above is the following *metatheorem* (3):

> For almost all paths connecting two points s_0, $s_1 \in Q$, the associated graph Γ admits only the four types of singularities shown in Figure 3.3.

These singularities are indeed those which can be observed on the level manifolds of a smooth real function F with n variables when one passes through a generic critical point (i.e. a non-degenerate critical point), this point being of index 0 (minimum), 1 (dichotomic scission), $n - 1$ (dichotomic confluence), n (disappearance).

The validity of these considerations reaches far beyond the relatively concrete (but exemplary) area we have been looking at. In particular, the dimension n of the ambient space does not intervene, any more than does the dimension of the control space Q. The "philosophical" importance of this "metatheorem" lies in the fact that it allows some control over the "generation" and "corruption" of entities (to use Aristotle's terminology) in so far as individuality has been reduced to no more than topological connectedness of the substrate.

If one were to consider variations of S involving more than one parameter, one would be able to obtain more complex singularities, for example triple vertices $\prec$ or intersections $\times$. (These singularities would require Q to be of dimension at least equal to three.) Such a solid body S, the position of which can cause "archetypal" transformations in

the topology of a flow, will be called a preprogram. We will show how this notion plays a fundamental part in animal morphogenesis as it does in human technology. Vital or technical realizations of archetypal singularities will be reviewed.

C. Examples of realization of archetypal singularities

TERMINAL CATASTROPHES 1 and 2. If we forego a temporal interpretation of the parameter x in favor of a *spatial* value, then singularities 1 and 2 are none other than the *boundary* singularity. This singularity, realized by $x \geq 0$, defines all situations where a flow is *channeled*, that is, not allowed to spread over into $x < 0$. This is a containment morphology: more often than not the boundary is thickened into an organ of rigid texture, like the dike holding back a river, the arterial wall containing blood, the skin enveloping an organism, the membrane around a cell. Every individual entity (every *individuating* pregnance) requires a surface able to control exchanges with the outside in an efficient way.

From a mathematical viewpoint many of the forms existing in biological morphogenesis and in technology are "almost effaceable". We say that a form F in the space $\mathbf{R}^n$ is *almost effaceable* if a homeomorphism h: $(\mathbf{R}^n,0) \rightarrow (\mathbf{R}^n,0_1)$ can be found allowing an arbitrarily small deformation δh such that $h + \delta h$ is a morphism admitting F as set of critical values. For example, $x \rightarrow y = x^3/3$ is such a homeomorphism deformed into $x \rightarrow x^3/3 - \varepsilon x$ where ε is arbitrarily small > 0; then the set of critical points of $h + \delta h$ is defined by $x^2 - \varepsilon = 0$. It is the curve $x = \pm \sqrt{\varepsilon}$, and on the target axis we have the end segment $\pm [-2/3\ \varepsilon^{3/2}]$. The almost effaceable form of $\mathbf{R}^3$ with a straight line as core gives rise to cylinders, to the innumerable canalizations that abound in the living world and in technology—vessels, pipes, electric conductors, cables, wires, etc.; the organs that ensure necessary *connections*.

An interesting case is that of a canalization-end (singularity of type 2). If the material flow cannot disperse freely outside (like smoke from a factory chimney), then it has to accumulate—at least for a *time*—at the *end point*. So this point must be *blown up* spherically, just as the axis blew out into a cylinder. Applied to a vertical segment of $\mathbf{R}^3$, this construction produces the *bottle* of Figure 3.4.

Generally, when there is inevitable disharmony in the circulation of a flow between production in α and consumption in ω, there have to be points somewhere along the trajectory $\alpha\omega$ where the flow material can be stocked. This will very often be achieved through a dead-end diversion from the global circuit ending in a spherical collector. (Take the example of the liver for energy transit in an animal.) Many modern

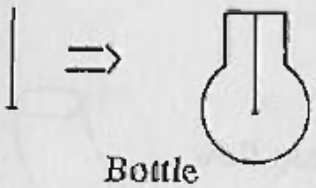


Figure 3.4

theoreticians—in the wake of Turing (4)—have sought to explain morphogenesis with the help of reaction-diffusion equations of the type $\partial x/\partial t = F(x) + k\Delta x$. In so doing they seem to forget that life is essentially a question of canalization, embankment and the struggle to stem dispersion. This is particularly easy to see in a phenomenon like the coagulation of blood, where a canalized *liquid itself* repairs gaps occurring accidentally in the vein wall. Similar processes are to be found in human technology (tubeless tires, for instance). The valve is a gap in the container wall stopped up by the pressure of the fluid *itself* and opening only as a result of stronger external pressure. In hydraulics, a fairly erosive water-course can, in a labile enough medium, make its own bed; the flow is then channeled by the very banks it has created.

Birth (singularity 1) raises a particular problem. If the created being is material, it cannot emerge from nothing (we are not concerned here with the materialization of energy in relativist physics!). In fact, in the typical case of a spring, or source, the water that wells up has a subterranean existence in the *form* of a vast underground network converging on the opening of the source (Figure 3.5). Matter hitherto invisible becomes visible. Most springs encountered in nature are of this type; they are due to a qualitative change in a material flow, occurring at the point where the flow converges. (The *funnel* is a device of this kind, creating a source from a diffuse flow.) The opposite kind of transformation, visible → invisible (singularity 2), may result from free *diffusion* or from a change of phase (Figure 3.6). Thus rivers like the Oued Draa, running southwards from the Moroccan Atlas, subsequently vanish in the Sahara, reduced to nothingness by evaporation and absorption into the sand. Singularity 3 can be realized in a watercourse, though this is rather exceptional (delta head). Later on we shall look at examples of the dichotomy of an asymmetrical energy flux; there is a natural course and an artificial one, obtained by some special operation like the creation of a diversion

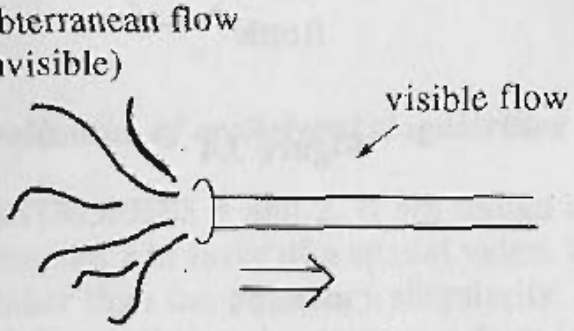


Figure 3.5

channel on a waterway, of which more will be said in section I. The sieve provides an example of qualitative scission. Singularity 4 of a material flow—the confluence of two streams—presents no great problem; in piped flows it is realized by means of the canalization section called in technical terms a "breeching" or Y-pipe (Figure 3.7). As the mixing of two fluids is an entropically favorable operation, two flows which are qualitatively different can merge together without difficulty (watering the wine.)

Generally, we will call *preprogram* any salient form immersed in a fluid flow, the movement of which can give rise to one or several archetypal morphologies in this flow. As a rule, if we can induce a singularity,

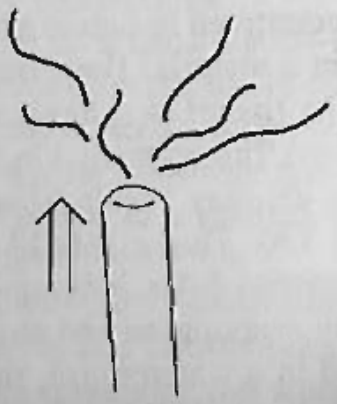


Figure 3.6 A flow ending in free diffusion

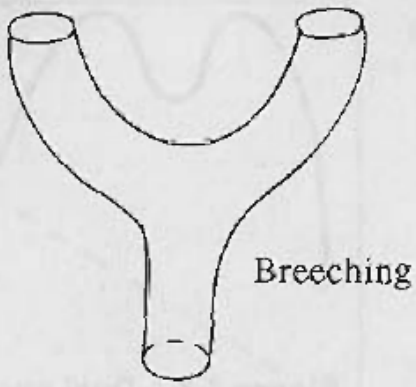


Figure 3.7

we can also bring about the "opposite" singularity (by inverting the time arrow). A tap, for instance, permits the *birth* or *death* of a flow according to whether it is on or off. The reversible character of the operation can be seen in the Hamiltonian nature of the movement (rotation of a spindle transformed into a translation by the thread of a screw). In this example, the operator exercises direct control; but even so a tap is more often very slightly on than completely off, as anyone with a house in the country will tell you—and, moreover, as genericity requires.

D. Mobile preprograms

A preprogram, subject to certain fixed connections, may be entrained by the current. If its control space is of dimension one, it may be drawn into a periodic movement, like rotation in the case of the mill-wheel. This can happen naturally too. A rock loosened from the bank of a torrent may be swept into a stable whirlpool and there hollow out a groove in which it continues to turn, so forming a pothole or giant's kettle. But a natural mobile preprogram of this kind serves no useful purpose, whereas the mill-wheel, as it turns, furnishes energy pumped from the current that moves it.

Mobile preprograms are amongst the oldest instruments known to man. Axe and knife, for example, are tools that accomplish the scission catastrophe. In catastrophe theory they correspond to the dual cusp (Figure 3.8) (5) which, projected at high speed onto a solid body, cuts it in two between the two faces. The *sieve*, another example, is a mobile form

Figure 3.8 Dual cusp

which allows small particles to be sorted from larger ones (the size of the mesh constituting the dividing value). In the same vein, we note that the *balance*, that earliest of scientific instruments, actually achieves the stabilization of an unstable equilibrium: we obtain, by means of (artificial) control, the potential of Figure 3.8, known as the dual cusp. Here we have an application of the *principle of the relativity of motion*. Instead of a fixed obstacle separating a mobile material in two, the obstacle is projected onto an immobile body (like the axe on a log). Mankind did not have to wait for Newton or Einstein to be familiar (albeit uncomprehendingly) with the relativity of movement. (The whole functional morphology of oral predatory organs is based on this principle.)

Propeller, pump and piston are so many mobile preprograms. In the more refined instances of technology, the position of the preprogram can, by coupling, cause the cocks which govern the admission or evacuation of the driving fluid to open or shut: think of the slide-valve of a steam-engine cylinder, or the valves of our internal combustion engines.

What is intended to ramify, in these last cases, is an energy flux. The emission morphology ⌒ is no longer interpreted materially, but in terms of energy. There exists a natural flow whose energy goes to waste, but from which man, by inserting a mobile preprogram, will be able to extract a current of energy to use as he sees fit. We have mentioned the mill-wheel. Its most primitive form was the Middle-Eastern *noria*, the function of which was precisely to bring about an auxiliary bifurcation in the flow of a watercourse by means of a moving wheel fitted with buckets which emptied into a diversion canal serving to irrigate land near the river. It is therefore important, at this point, to take another look at mill-wheel theory.

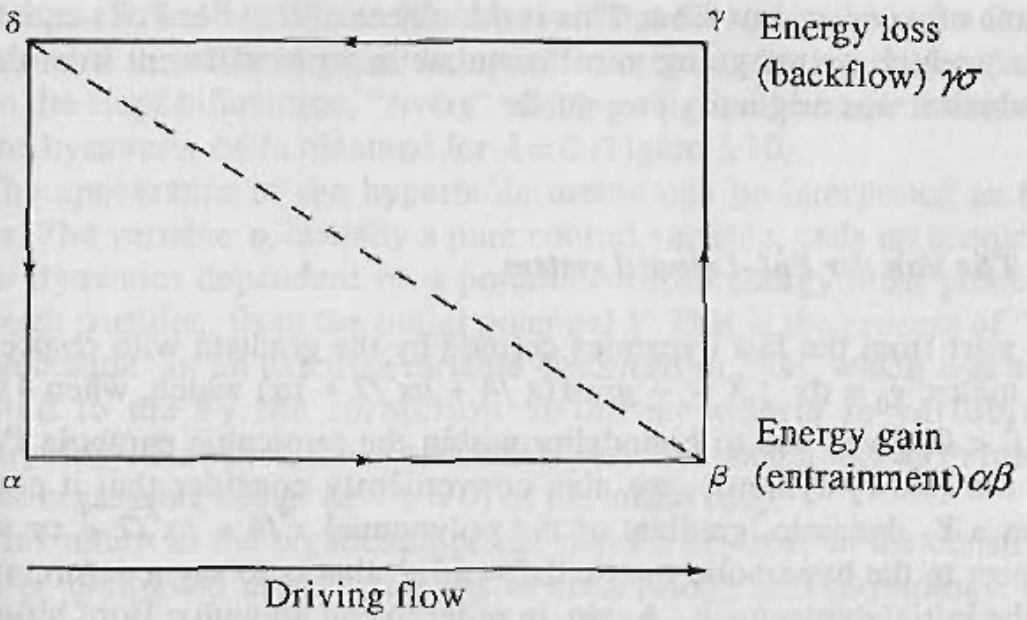


Figure 3.9

E. Mill-wheel theory

Let us consider a mill-wheel in its simplest form with only one blade, This blade has two possible positions. Either it is (at least partly) immersed in the river water, or it is in the air. In the first case, the entrainment phase, it is driven by the current. In the second case, the rotation of the blade's axis is slowed down by various dissipations, by friction, or by the work required of machines fitted to the axis. Whence the theoretical "hysteresis loop" schema of Figure 3.9.

Transitions $\delta\alpha$ and $\beta\gamma$ are assumed to be very fast (catastrophic). The schema is that of a violin string vibrating beneath the bow. When the transversal speed u of the string has the same direction as the speed v of the bow (positive, for example), there is a strong friction coefficient and the string receives energy from the bow. When the string comes back in the other direction (negative in our example), the friction coefficient f is much weaker, and the string consequently loses less energy than it gains in the driven period. This energy gain keeps the string vibrating; its energy is dissipated in causing the ambient air to vibrate (and in thermal dispersion). The same schema holds for the escapement of a clock—a device invented in the Middle Ages, long before any theory of mechanics.

It is important here to review the theory of the link between the cusp catastrophe and devices such as these for maintaining oscillation by means of a continuous flow. This is the object of Van der Pol's equation theory which we are going to re-formulate in terms different from those in which it was originally presented.

F. The Van der Pol–Liénard system

We start from the fast dynamics defined by the gradient with respect to the metric $g_0 = dx^2$: $X = -grad_x(x^4/4 + \mu x^2/2 + vx)$ which, when $4v^3 + 27v^2 < 0$, gives rise to bimodality within the semicubic parabola P. As for the (slow) dynamic, we may conveniently consider that it comes from a Y_λ dynamic, gradient of the polynomial $x^4/4 + ux^2/2 + vx$ with respect to the hyperbolic metric $dx^2 - \lambda dv^2$, that is to say a deformation of the initial dynamics g_0. Again, in order to end up with a Hopf bifurcation for $\lambda = 1$, we must have the potential $x^4/4 + vx$ (for the gradient of vx with respect to the metric $dx^2 - dv^2$ is the same as the symplectic gradient of $v^2 + x^2$ with respect to the symplectic form $dx \wedge dv$, that is, the linear oscillator). This shows that the coefficient u in X above, as a function $u(\lambda)$ of the parameter λ, has to satisfy $u(1) = 0$ and $u(0) = -1$. Hence we may suppose $u(\lambda) = \lambda - 1$. For $\lambda = 1$, the field S_1 presents the Hopf bifurcation in O when λ goes from $1 + \varepsilon$ to $1 - \varepsilon$: for $\lambda = 1 + \varepsilon$, the field $S(\lambda)$ has in O a stable attractive point; for $\lambda = 1 - \varepsilon$, it becomes a stable attracting cycle around O, which, when λ describes the interval from $1 - \varepsilon$ to 0, is continuously deformed into the hysteresis loop associated with the cusp.

More precisely, the gradient of a function $F(x,v)$ with respect to the hyperbolic metric $dx^2 - \lambda dv^2$ is proportional to $G = 1/\lambda\ \mathrm{grad}_x F - \mathrm{grad}_v \mu$ when grad_x, grad_v denote the gradients with regard to the metrics dx^2, dv^2 respectively (degenerate metrics, the unrepresented variable being taken as parameter in the gradient). Indeed, the scalar product of two vectors (X,V), $(\delta x, \delta v$, with respect to this metric, is $X\delta x - \lambda V\ \delta v$. This product must be equal to $dF\ (X,V) = F_x \delta x + F_v \delta v$. Whence, by identification,

$$X = F_x, -\lambda V = F_v, \text{ or } X = F_x, V = -1/\lambda \cdot F_v$$

Applied to $F(x,v) = x^4/4 + (-1 + \lambda)x^2/2 + vx$, this gives $X = x^3 + (-1 + \lambda)\ x + v$, $V = x/-\lambda$ or, after multiplication by λ, $G = \lambda[x^3 + (\lambda - 1)x + v] \partial/\partial x - x\ \partial/\partial v$.

It will be observed that this field as function of λ never has more than one singularity, namely the origin $O(x = v = 0)$. This point is an attractor

for $\lambda > 1$, a repeller for $\lambda < 1$, with the classic Hopf bifurcation in $\lambda = 1$. Explicit integration of this differential system is achieved by the elliptic functions. F. and M. Diener (6) observed that for values between 0 and 1, $1 > \lambda > 0$, the field presents, apart from the attractive cycle arising from the Hopf bifurcation, "rivers" which prefigure the stable manifolds of the hysteresis cycle obtained for $\lambda = 0$ (Figure 3.10).

The appearance of the hyperbolic metric can be interpreted as follows. The variable v, initially a pure control variable, ends up acquiring slow dynamics dependent on a potential whose energy must proceed, through partition, from the initial potential V. This is the process of "internalization" of an external variable described in *SSM*, which was suggested to me by the formation of the mesoderm in vertebrate embryology. However, the coefficient u varies in such a way as to return to the organizing center ($u = v = 0$) of the initial cusp.

This return to the organizing center plays a key role in the construction of biological models relating to embryology and physiology. We shall come back to this important point later on (Chapter 5, section H). But the problem can be approached from another angle.

G. Technique and nature

Throughout history technology has played an important part in our interpretation of vital phenomena. As early as the sixteenth century, when anatomy came into existence with the work of Vesalius and Harvey, the way different organs functioned was pictured by analogy with man-made instruments. The heart was seen to be a pump sending blood through vein and artery canalizations; the lungs were a pair of bellows; the limbs, with their articulations, lent themselves to obvious mechanical analogies. Thus came into being the Cartesian theory of the machine-animal... Such analyses have been pursued throughout the history of biology.

The most recent—and perhaps the most famous—has of course been the assimilation of neuron wiring in the brain to the structure of a computer (and let's not forget the application of the genetic code metaphor to chromosomal DNA). One cannot deny that there is something to be said for these analogies. Where they have turned out to be false it has been because they were incomplete and because a good part of the organic function had escaped the experimenter's eye. Aristotle, however, had pointed out, long before, that "It is not nature that imitates art, but indeed art that imitates nature" (Aristotle, *Protreptics*, fragment 11,

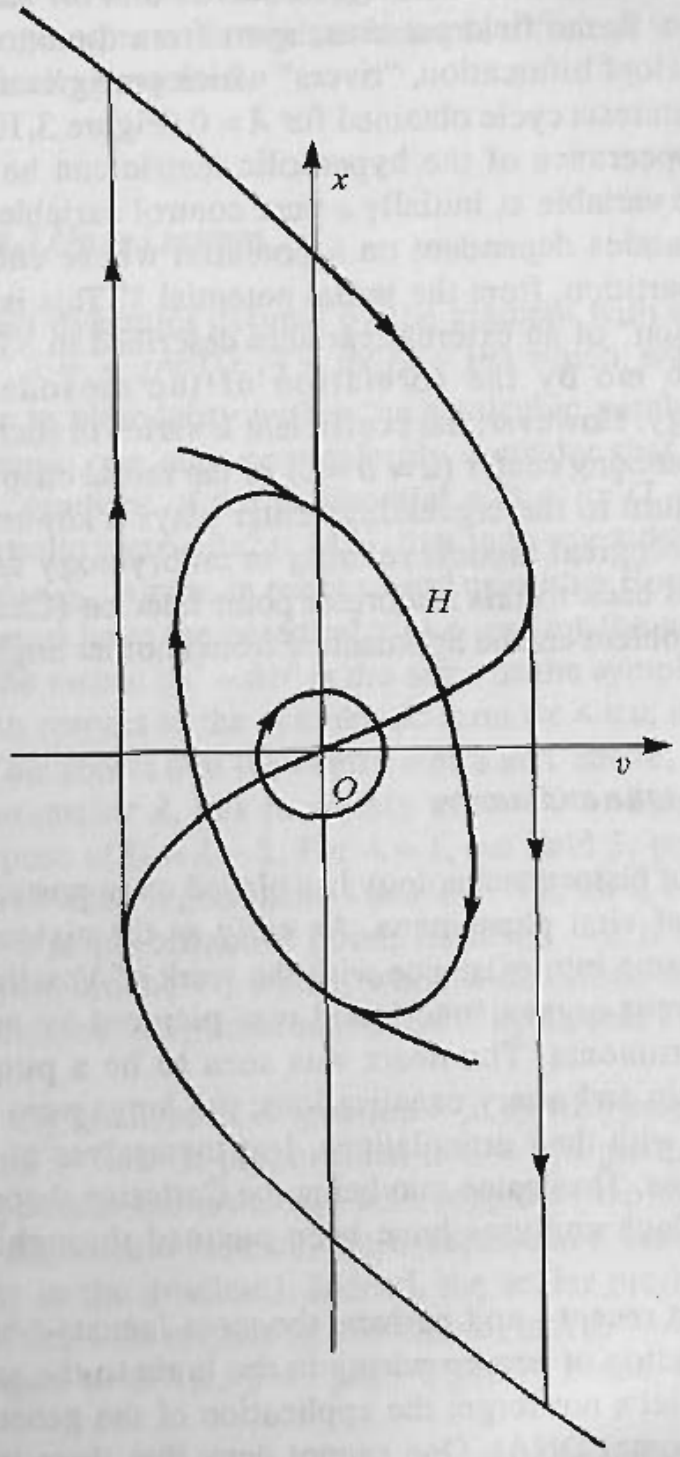


Figure 3.10 Deformation of a cycle resulting from a Hopf bifurcation into a hysteresis loop (Van der Pol's theory). Observe the beginnings of the stable curves as "affluent rivers". From *Complexity, Language and Life: Mathematical Approaches, Biomathematics*, Vol. 16, Springer-Verlag, 1986, p. 214.

Waltzer). Thus was inaugurated a vitalist tradition which, from the Stagirite to Bergson, never quite died out. For the fact remains that an instrument *is* the material prolongation of an organ: it is the vector of a pregnance of biological origin, the support of an action, and the outward extension of this organic activity. That is why there is nothing absurd—pedagogically at least—about making use of technical analogies in order to understand some of the most fundamental mechanisms of ontogeny.

H. Duplication of the hysteresis loop in purposeful activities

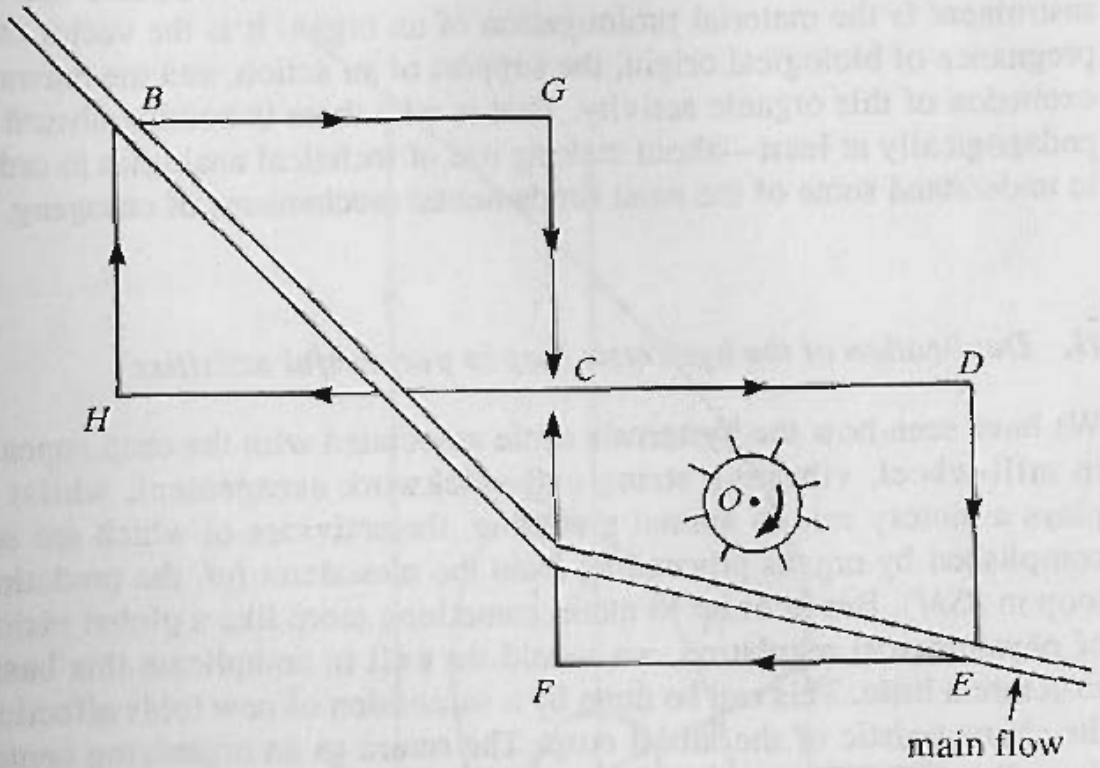
We have seen how the hysteresis cycle associated with the cusp appears in mill-wheel, vibrating string and clockwork escapement, whilst it plays a motory role in animal predation, the activities of which are accomplished by organs proceeding from the mesoderm (cf. the predation loop in *SSM*). But in order to attain something more like a global vision of physiological regulation, we would do well to complicate this basic structure a little. This can be done by a succession of new folds affecting the characteristic of the initial cusp. The return to an organizing center thus allows us to pass from the singularity $V = x^3$ to the singularity $V = x^5$, as the quadratic potential $V = x^2$ can be complicated into $V = x^4$.

This type of complication will present itself when we consider the mill-wheel technique. It was very soon realized that mill-wheel performance was improved when the current was faster. Whence the idea (which probably emerged in ancient times) of turning aside part of the current into a low-gradient diversion canal, thus creating an artificial waterfall below which the mill-wheel could be placed.

In mathematical terms, the construction of a diversion canal can be considered as due to the presence of a complete "backflow" *CH* + *HB* representing the containment effect of a dam which in partly shutting off the normal course of the water by means of a sluice will feed the diversion canal (in *B*). The fall *GC* is the "catastrophe" and the backflow is the edge *CH;* this is a fictitious counter-current that "symbolizes" the damming (Figure 3.11).

The mill-wheel *O* is also the centre of the hysteresis loop inscribed in the rectangle *CDEF; FC* represents the entry of the blade in the waterfall, *DE* its exit. The edge *CD* is the entrainment period, *EF* the period of dissipation.

In this device it is essential for the points *G*, *C* and *F* to be on the same vertical line, in other words for the catastrophic segments *GC* and *FC* to end up at the same point *C* on the horizontal *HD*. The late lament-



BG Diversion canal

GC Waterfall

FC Blade enters the fall

CD Entrainment by the current

DE Blade comes out of the fall

EF Dissipation

CH Backflow (containment of the dam in B)

Figure 3.11

ed José Argémi (7) called these projections of *G* and *F* in *C* the *cofold* points associated respectively with the fold points *G,F*. It is this *cofold coincidence* that expresses the *finality* of the earlier process (rectangle *CHBG*) with respect to the later process *FCDE* which is the properly ef-

ficient part of the whole structure. If it may be said that "the end justifies the means", one ought to note here that from a "phylo- and onto-genetic" point of view, "the end secretes its own means". We shall come back later to the "Platonic" character attributed by our model to biological functions.

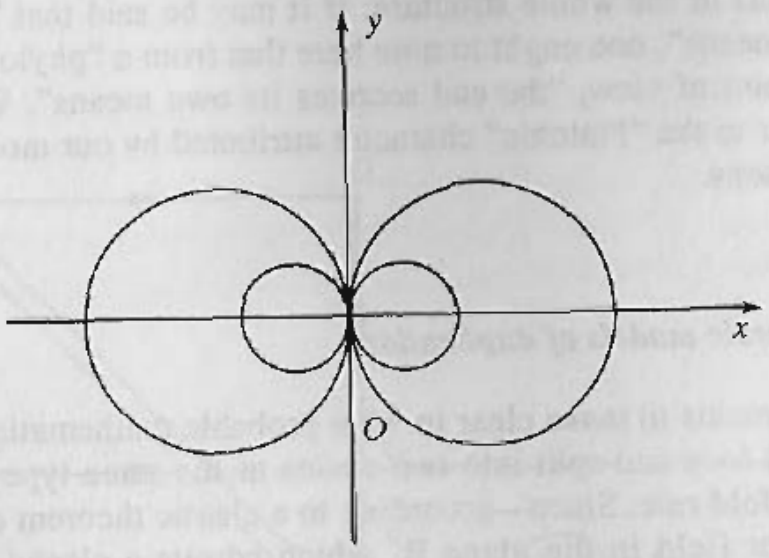
I. Algebraic models of duplication

It now remains to make clear in what probable mathematical structure a hysteresis loop can split into two cycles of the same type concatenated by the cofold rule. Since—according to a classic theorem of Poincaré—any vector field in the plane $\mathbf{R}^2$ which admits a closed trajectory or cycle admits at least one singular point inside it (a focus), the scission of the cycle G of focus O requires that the singularity O be first split into two points. This necessitates the preliminary *stopping* at focus O of local rotation around O (i.e. the stopping of the *performing* character of the process). We can then imagine two scenarios:

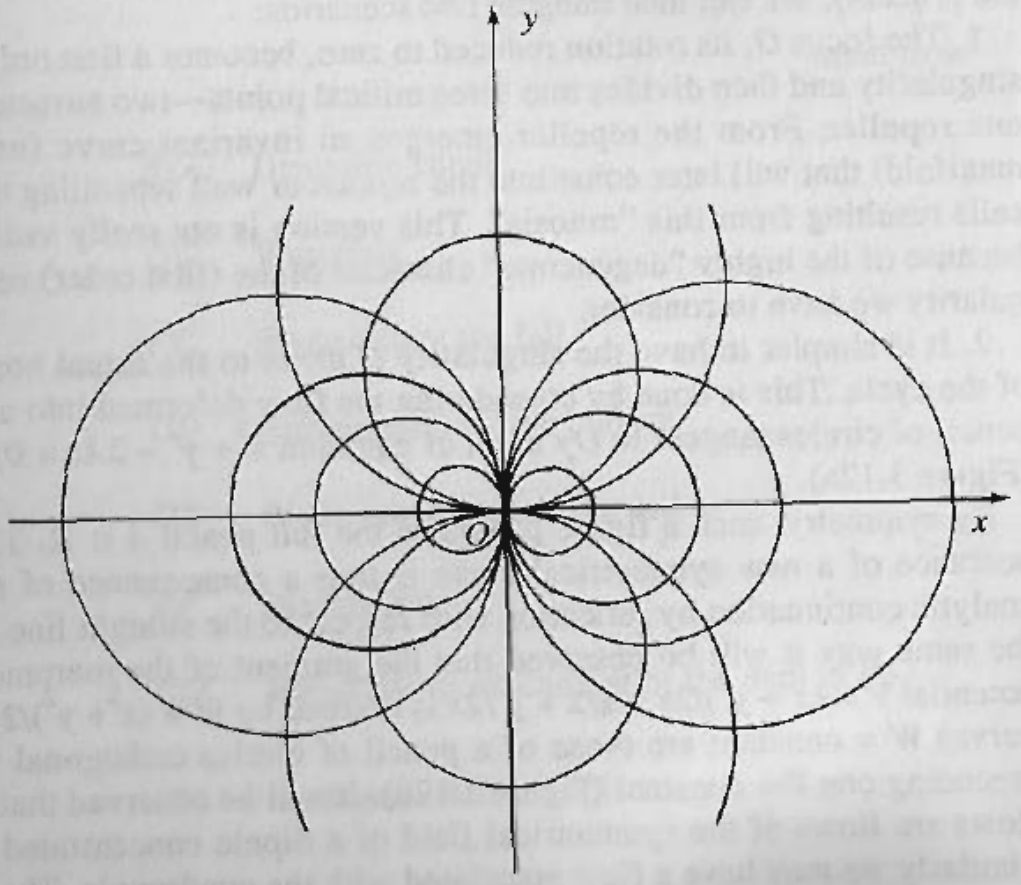
1. The focus O, its rotation reduced to zero, becomes a first order zero singularity and then divides into three critical points—two attractors and one repeller. From the repeller emerges an invariant curve (unstable manifold) that will later constitute the *septum* or wall separating the two cells resulting from this "mitosis". This version is not really satisfying, because of the highly "degenerate" character of the (first order) zero singularity we have to consider.

2. It is simpler to have the singularity O move to the actual boundary of the cycle. This is done by considering the flow deformed into a linear pencil of circles tangent to Oy in O, of equation $x^2 + y^2 - 2\lambda x = 0$, $\lambda > 0$ (Figure 3.12a).

By symmetry, such a figure generates the full pencil $\lambda \in \mathbf{R}$. The appearance of a new symmetrical cycle is thus a consequence of simple analytic continuation by reflection with respect to the straight line Oy. In the same way it will be observed that the gradient of the meromorphic potential $V = (x^2 + y^2)/2x = x/2 + y^2/2x$ is defined by $W = (x^2 + y^2)/2y$. The curves W = constant are those of a pencil of circles orthogonal to the preceding one V = constant (Figure 3.12b). It will be observed that these flows are flows of the symmetrical field of a dipole concentrated in O. Similarly we may have a flow associated with the quadrupole. The splitting up of this foursome made up of two couples (a^+a^-) (b^+b^-) along the two lines of scission (a^+b^-) (a^-b^+) or (a^+a^-) (b^+b^-) is a model which could represent the cleavage of the DNA double helix.



a. Duplication of a plane cycle by degeneration into a pencil of circles



b. Degeneration into two orthogonal pencils of circles. Extract from *Complexity, Language and Life: Mathematical Approaches*

Figure 3.12

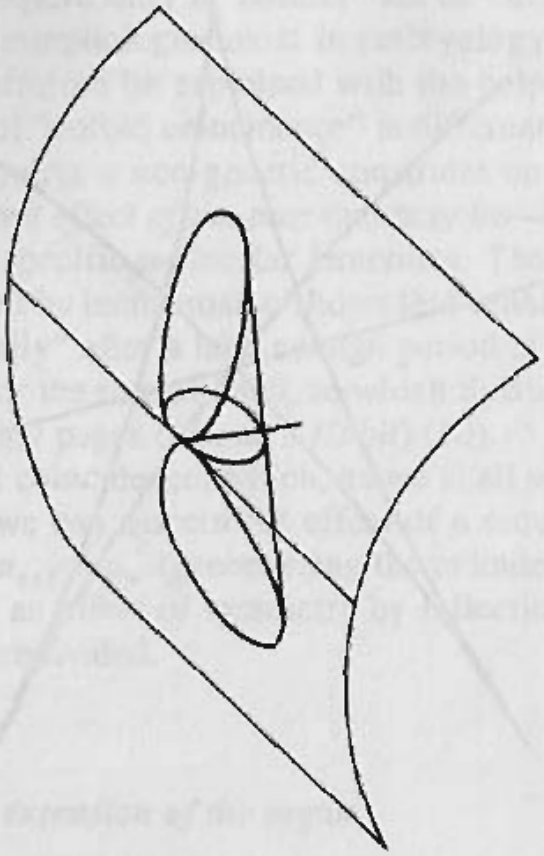


Figure 3.13 Intersection of a parabolic cylinder with a tangent cylinder

We should also note that these scenarios concern vector fields of the plane $\mathbf{R}^2$. As soon as one is in a space of, say, dimension ≥ 3, the splitting of a cycle becomes much easier, for it no longer requires a preliminary scission of punctual singularities. This has recently been studied by Coullet, Gambaudo and Tresser (8). As we shall see in Chapter 5, this preliminary scission is linked with the existence of the genome.

It remains to account for "cofold coincidence" in a saddle point of the duplicated dynamics. To the previous model of a pencil of circles we add a dimension z, and so form the parabolic cylinder z of equation $z - x^2 = 0$; we then denote by π the projection $Z \to \mathbf{R}^2$ induced by $(x,y,z) \to (x,y)$. The counter-image π^{-1} of a circle Γ of the pencil is then, in the cylinder Z, a figure of eight which realizes the double concatenated loop quite well. (Note that on $Z < 0$ the direction of the induced flow has to be reversed (Figure 3.13).

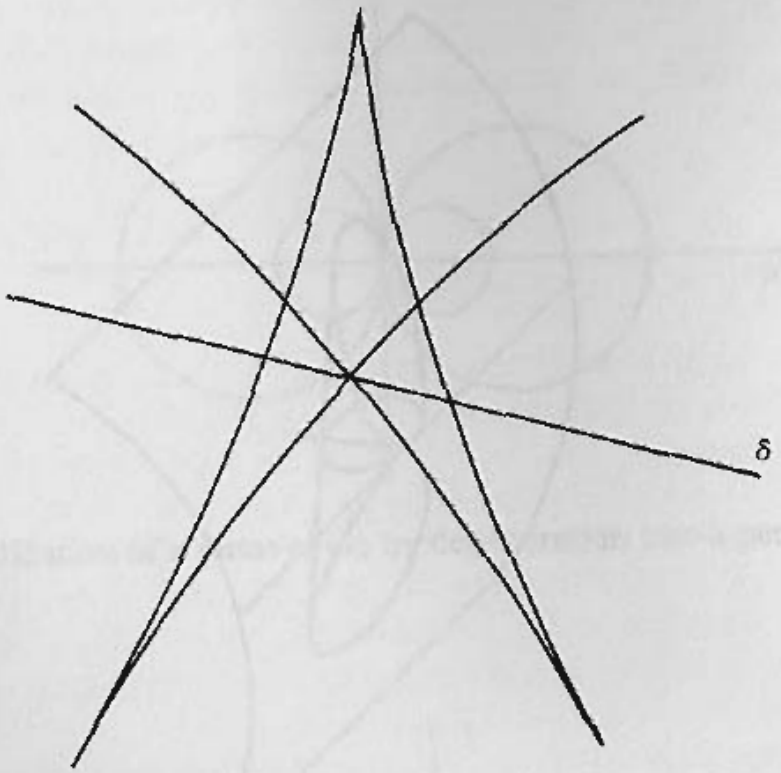


Figure 3.14 Section of butterfly unfolding leading to cofold coincidence

In elementary catastrophe theory, a double hysteresis loop like that in Figure 3.11 comes from the butterfly singularity, associated with the potential $V = x^6/6 + u\,x^4/4 + v\,x^2/2 + wx$. But to realize cofold coincidence, we must have, in the control space (u,v,w) containing the "butterfly" curve, a rectilinear section that passes through the axial double point (Fig. 3.14).

J. Genetic constraints and catastrophe theory

During a talk I gave in 1968 at the Wistar Institute in Philadelphia (9), one of the audience of biologists raised the following objection: "In the morphogenesis theory of the theory of elementary catastrophes, 'memory', an effect of the past, plays no part (these morphologies being 'independent of the substrate'). Yet in biology all morphology is based on an effect of memory, a genetic acquisition, as is proved by the impossibility of spontaneous generation."

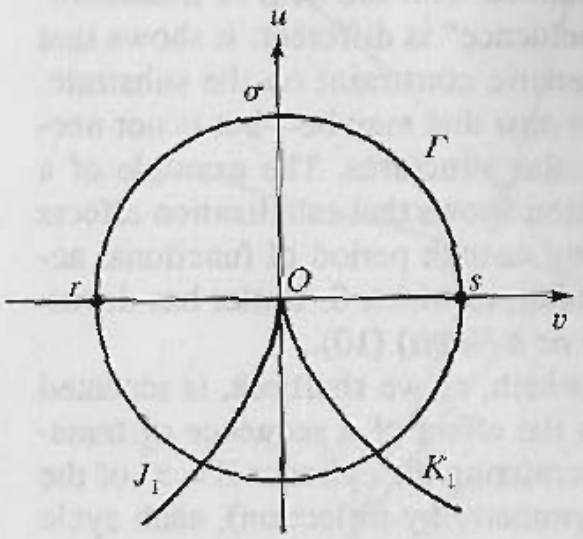
This objection provides food for thought. In fact there are generic morphologies which require only a "natural" set of circumstances for their realization. Such morphologies exist in embryology. They are not "canalized" and can therefore be explained with the help of a catastrophe schema. The case of "cofold coincidence" is different: it shows that such a morphology requires a non-generic constraint on the substrate, consequently a very strict *effect of the past* that may be—but is not necessarily—attributed to specific molecular structures. The example of a river making its own bed by bank erosion shows that canalization effects can come about "naturally" after a long enough period of functional activity. The same goes for the role of habit, to which S. Butler has devoted some very illuminating pages (*Life as a Habit*) (10).

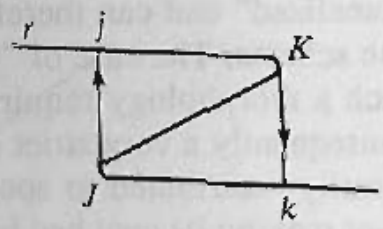
In the case of cofold coincidence, which, as we shall see, is repeated in animal physiology, we can discern the effect of a sequence of transformations of the type $u_{n+1} = u_n^2$ (generalizing the cylinder $Z = x^2$ of the preceding section, it is an effect of symmetry by reflection), each cycle being dichotomically subdivided.

K. The instrument as extension of the organ

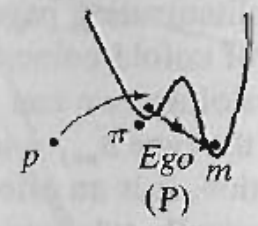
Anticipating somewhat on what we shall have to say about embryology in Chapter 4, we recall the "predation" loop already introduced in *SSM*. In the canonical cusp $V = x^4/4 + u\,x^2/2 = vx$ (Figure 3.15a), we consider a circle Γ of the control plane Ouv, and we lift this circle into the slow manifold of equation $x^3 + ux + v = 0$. In the bimodality zone (inside of $4u^3 + 27v^2 > 0$), the two minima denote predator P and prey p. The segment rj of Figure 3.15b designates the hungry predator, so alienated as to be one with his prey, a state we call $P^{(p)}$. In the model "predation loop revisited" given in Chapter 4, section C, this state of "privation" is represented by a zone of bimodality (potential V with two minima, where the predator $P^{(p)}$ occupies the highest minimum, the position of metastable equilibrium). Thus we have the statement "Privation is the beginning of metastability" which we will find again in Chapter 7, section D. The situation is that of Figure 3.15b: as soon as the predator P encounters a prey p that he recognizes as such, the *perception catastrophe* will take place. The prey's pregnance invades him, showing itself in a "tunnel" effect on the potential of Figure 3.15c. The predator P leaves the top minimum π, dropping (through the tunnel) to the basic minimum m. He is once more himself, *Ego*, a predator, and the prey pursued p will occupy the high minimum π left vacant by the predator (cf. Figure 1.3). Then comes the pursuit of the prey p which, in the normal sequence of events (Figure 3.15b), ends up with capture at the fold point K. During

a. Predation jump





b.



J_1 Perception catastrophe
K_1 Capture catastrophe

c. Compare with Figure 1.3

Figure 3.15

this time, the whole predator-prey system covers the segment *Jk* of the control plane *Ouv* on the straight line of capture. Actual ingestion of the prey *p* is represented by the vertical segment *Kk*, fold-cofold.

We now examine the classic case of Köhler's chimpanzee getting hold of a stick to knock down a banana hanging out of reach. The "scenario" is as follows. On catching sight of a banana, our (hungry) ape will first try to reach it with his hand. When he finds that it is too high, he experiences a feeling of frustration, of "suffering". Now affectivity "deforms" the organism's regulatory structure by complicating it. The characteristic associated with the capture segment *Jk* returns to the organizing center ($u = 0$) and then develops an inflection in $V = x^5$ (Figure 3.16a) that subsequently unfolds in two concatenated cycles $0JjB + 0Kk\alpha$ (Figure 3.16b). The monkey, alienated into a stick $P^{(b)}$, is represented by the edge *J0* of the first cycle. The transformation $(P^{(b)})^{(p)} \to (P^{(p)})^{(b)}$ symbolizes the insufficient length of his arm. If he finds a stick, the capture catastrophe will take place, transforming him into $P_b^{(p)}$, and the dynamics will be reduced to the single cusp (Figure 3.16d), becoming a classic capture when the stick *b* reaches the banana.

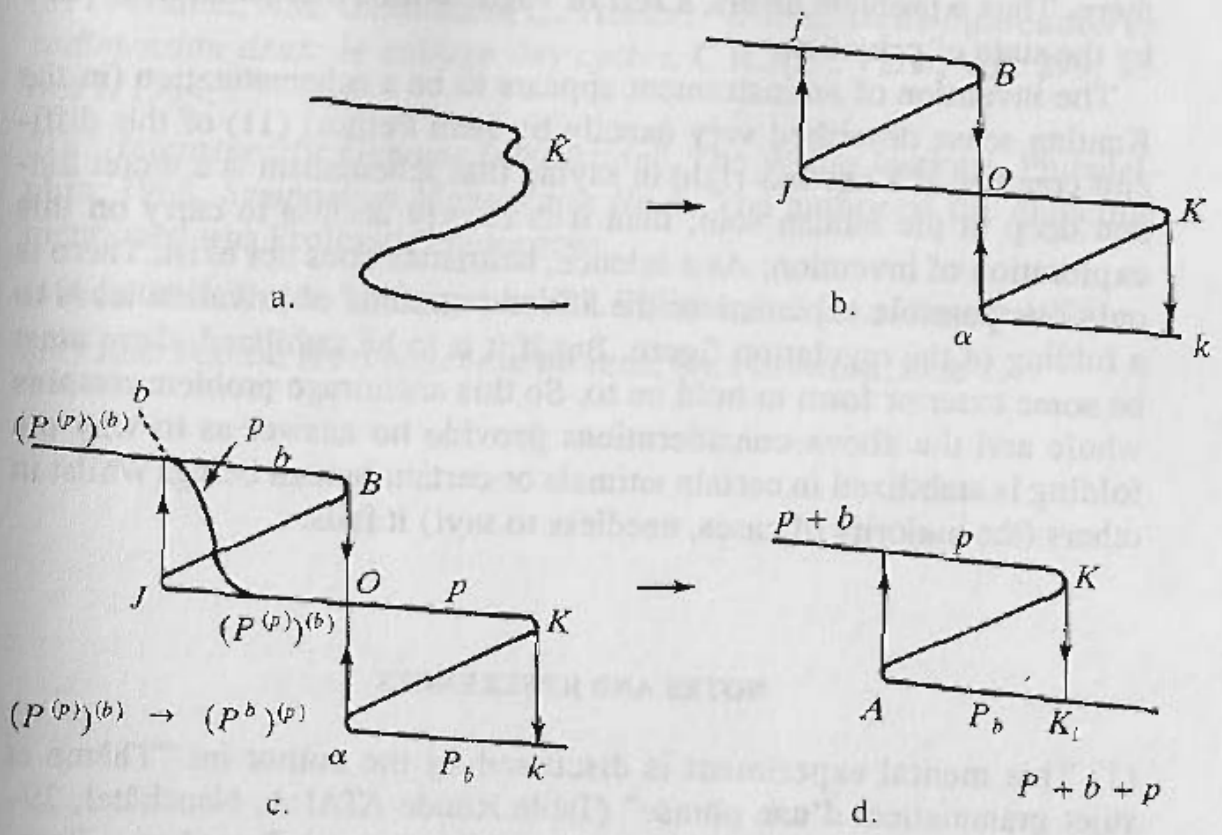


Figure 3.16

The problem here is in understanding why this process should exist in primates and not in other animals. (We know, however, that certain birds do use stones to break eggs and stalks to get grubs out from crannies in the bark of trees.) It is quite likely that there was some invention at the start which was then "culturally" fixed. If we think of the upper half of the circle in Figure 3.15a, $u > 0$, $s\ \sigma\ r$, as being that of *sleep and dreaming*, this trajectory transforms the sated predator P_p into the hungry predator $P^{(p)}$, alienated by the image of his prey. That is to say that this sleeping phase changes the material remains of the prey (in the throes of assimilation) into a mental image of this same prey. If this process is somehow stimulated (in the sense of concept excitation described in Chapter 1), the prey may well take on an amplified appearance. The banana our chimpanzee cannot reach will become a "prosthetic" banana of inordinate length. When the dreamer awakes, comparison with the actual length will produce the idea of a capture "prosthesis", the transformation $P \rightarrow p^{(b)}$. As Th. Adorno put it, "The means tip the scale to become an end in themselves". What is strictly speaking the end—to take the banana—must be set aside in order to concentrate on the means of getting

there. Thus a problem arises, a sort of vague notion altogether suggested by the state of privation.

The invention of an instrument appears to be a schematization (in the Kantian sense described very exactly by Jean Petitot) (11) of this difficult concept. If Kant was right in saying that schematism is a secret hidden deep in the human soul, then it is clearly useless to carry on this exploration of invention. As a science, heuristics does not exist. There is only one possible explanation: the affective trauma of privation leads to a folding of the regulation figure. But if it is to be stabilized, there must be some exterior form to hold on to. So this anchorage problem remains whole and the above considerations provide no answer as to why the folding is stabilized in certain animals or certain human beings whilst in others (the majority of cases, needless to say!) it fails.

NOTES AND REFERENCES

(1) This mental experiment is discussed by the author in: "Thème et sujet grammatical d'une phrase" (Table Ronde ATALA, Neuchâtel, 29–31, May 1980) in "*Linguistique et Mathématiques* ed. Peter Lang, Bern-Frankfurt, 1982.

(2) A study of the obstacle problem (looked at from the quantitative point of view, of course!) is to be found in V.I. Arnol'd, *Catastrophe Theory*, 2nd edition, Springer-Verlag 1980, 63–66.

(3) More precisely: the space $\mathcal{L}(Y)$ is endowed with a canonical stratified set H of codimension one defined as the set of all real smooth functions $\mu(y)$ which admit 0 as critical value. Then the morphism $\tilde{\mu} : Q \to L(Y)$ has to be supposed smooth and *transversal* with respect to the set H in $L(Y)$.

(4) A.R. Turing: "The chemical basis of Morphogenesis", *Philosophical transactions of the Royal Society*, B, 237, 1952.

(5) **Dual cusp.** See E.C. Zeeman, *Catastrophe theory*, Addison-Wesley, Reading, Massachusetts, 1977, p. 60.

(6) Francine and Marc Diener: "Fleuves", *Actes de l'Ecole d'été "Analyse non standard et représentation du réel*, OPU Algiers and CNRS Paris, 1985, 111–130.

See also Marc Diener: *Détermination et existence de fleuves en dimension deux*, C.R.A.S., Paris, Vol. 301, series I, No 20, 1985, p. 899.

(7) José Argémi—Mireille Canalis: "*Coplis associés à un polynôme de degré n*", C.R.A.S., Paris, Vol 299, series I No. 9, 1984.

(8) P. Coullet, J.M. Gambaudo, C. Tresser: *"Une nouvelle bifurcation en codimension deux: le collage des cycles*, C.R.A.S., Paris, Vol. 299, series I, 1984, 253-256.

(9) *"Heterospecific Genome Interaction"*, The Wistar Institute, Philadelphia, 1968. *Symposium Monograph No 9*. The author of the objection mentioned was Professor Pontecorvo.

(10) Samuel Butler, "Life as a habit", Trübner and Co., London 1978.

(11) Jean Petitot, *Morphogenèse du sens*, see Foreword, note 1.

CHAPTER 6

ARISTOTELIAN DYNAMICS SEEN AS SEMIOPHYSICS

Here we shall be looking at Aristotle's doctrine from a "catastrophist" angle. To start with, we present a set of axioms from Aristotelian dynamics transcribed into the terminology of modern qualitative dynamics (1).

A. Axiomatics

I. The world is made up of entities (οὐσίαι) (2).

II. All entities suppose the existence of a *substrate* (ὑποκείμενον). For what we call *primary* entities, this substrate is a *material* set and consequently spatial in $\mathbf{R}^3 \times T$ (T time). The non-primary entities, called secondary entities, have their substrate in an abstract space consisting of intelligible matter (ὕλη νοητή) (3). Two entities with the same substrate are identical. The datum of the substrate in its ambient space characterizes the entity (*hic et nunc*). We shall denote by $|A|$ the non-empty substrate or support of the entity A.

III. DISJUNCTION OF ENTITIES. If $|B| \subset |A|$, B is said to be part (μέρος) of A (4).

IV. AXIOM OF SEPARABILITY. If two entities A and C have non-disjoint supports in the same space, then there exist two entities $A \cup C$, $A \cap C$ such that $|A \cup C| = |A| \cup |C|$ and $|A \cap C| = |A| \cap |C|$. An entity with *connected* support is said to be individuated (ὅλον).

V. AXIOM OF LOCALITY. In general (ὡς ἐπὶ τὸ πολύ) individuated entities have non-empty interiors (balls, in fact); then if A and B meet and interact, this interaction has its support on the frontier σA of A and on that of B, hence in $\vartheta|A| \cap \vartheta|B|$. A and B are then said to be *in contact* (ἁφή).

VI. STATE OF AN ENTITY (διάθεσις). Suppose it possible to find two primary entities A_1, A_2 such that there exists a Euclidean shift of $\mathbf{R}^3 \times T$, D such that $|A_2| = D|A_1|$ and that the displacement D transforms the whole neighborhood of A_1 into a neighborhood of A_2 insofar as the entities therein and their sensible properties are concerned. A_1 and A_2 are then said to be in the same *state*. (The state is characterized by phenomenal equivalence, *modulo* a Euclidean shift.)

VII. POTENTIALITY. The states of an entity A form a set $S(A)$. The entity A may be subject to various disturbances (movement or deformation). This deformation signifies only for primary entities (with material support); secondary entities are generally considered to be fixed. There is, in theory, no geometry in a space of semiotic nature like the space of a genus; but there is a mental continuum where deformation is possible. This means that the notion of potentiality can be applied to secondary entities. However, its *substrate must be permanent* (up to a homeomorphism) if the permanence of its individuality is to be ensured. We are thus able to define a class of entities associated with A (all those with representatives equal to deformations of A). This being so, we write (A,α) for each entity A in the state α. If there exists a temporal evolution which can conceivably be realized, transforming (A,α) into (A,β), then it will be said that (A,β) proceeds from (A,α) or that (A,β) is *within the potential* of (A,α) (notation $(A,\alpha) \rightarrow (A,\beta)$).

We now construct the oriented graph Γ_A obtained by joining vertex α to vertex β by an oriented arc $\overrightarrow{\alpha\beta}$. We define a relation of equivalence ρ in Γ between two vertices (x,y) of Γ_A *if there exists an oriented path from* x to y in Γ_A, and likewise from y to x. Then the graph quotient $\Gamma_{A/\rho} = \tilde{\Gamma}$ has no cycle and projects onto the time axis.

The irreversibility of certain transformations is thus made manifest: every man alive is a potential corpse, but the converse is not true. (This is not a true example in the spirit of strict Aristotelianism. Indeed, according to Aristotle, the corpse, deprived of soul, has lost the form of the living body, and is not an *ousia* (cf. Meteorologica IV, 390a, 24)).

VIII. NATURAL TRANSFORMATIONS (κατὰ φίσιν). Among the transformations affecting a being, we may distinguish those which are "natural" or "generic" (ὡς ἐπὶ τὸ πολύ): they form a subgraph Γ_A^g,

with its quotient $\Gamma\Theta_A^g$. States not belonging to Γ_A^g are said to be "accidents" of A (συμβεβηκός). Every transformation $(A,\alpha) \to (A,\gamma)$ in an accidental state requires the interaction of entities other than A, acting through contact with A. Inversely, most "solitary" evolutions of A are "natural" (but not necessarily irreversible: take the case of sickness). If an entity's support is required to be connected, then for each instant t the graph of $\tilde{\Gamma}$ consists of all possible states at an "age" t.

REMARK. Certain natural transformations of a being require the presence of other entities. For example, the passage new-born babe → child demands the presence of a nurse (the mother, usually). Such a presence is "natural". Moreover for a being to come into existence, the presence of at least one parental entity is required in order to provide a substrate that is then *severed* from the parent.

B. τέλος, τέλειον *and* τελευτή: *birth and demise of an entity*

Since the only eternal entities are those of the supralunar world (the firmament and the stars), all entities here below have a beginning (γένεσις) and an end (φθορά). Whence a graph $\tilde{\Gamma}$ limited in time, generally culminating in a unique vertex, the end (τελευτή), sometimes identified with the τέλος. For man placed in the context of his species, we have the transformation man → child *via* the relationship of begetting. Whence the graph 6.1 of natural transformations of the species.

This time there is a cycle, and the "time" function reaches its maximum at the adult age. This is the τέλειον, the "perfect" state, to be clearly distinguished from the terminus (τελευτή). The τέλος appears to oscillate between these two meanings, τέλειον and τελευτή, an ambiguity which does not seem to bother Aristotle unduly but which often does raise a problem.

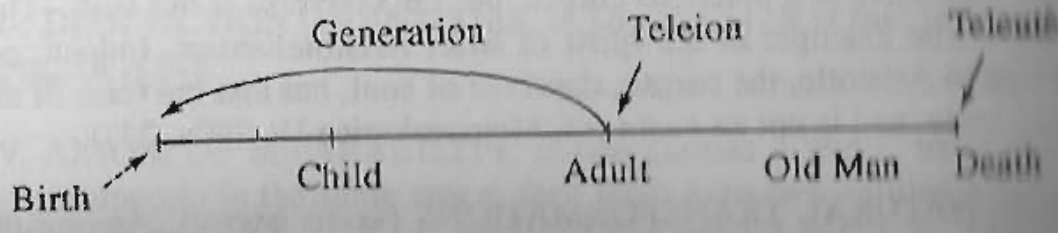


Figure 6.1 Birth, telos and end of an entity

Quotation [1] seems to indicate that the τέλος is in a way the *central* point of the existence of an entity or an act: it determines both what precedes (τὸ πρότερον) and what follows (τὸ εφεξῆς). From the catastrophist viewpoint, the τέλος could thus be seen as the *organizing center* of a morphogenetic field of beings and events evolving in time. In this case the τέλος should always be distinct from the τελευτή.

C. *"Potentiality" defined by mental experience*

"Potentiality" as we define it: $(A,\beta) \leftarrow (A,\alpha)$, or (A,β) within the potentiality of (A,α) requires the existence of a transformation changing A from state α into state β. In a more general way, the notion of potentiality is extended, in Aristotle, to "mental experiences"; the fact that one can *conceive* the possibility of such and such a transformation from α into β suffices for us to be able to say that β is within the potentiality of α. From this point of view there is a profound ambiguity in the expression "potential being" (τὸ δυνάμει ὄν). For a being can be potential in the sense that it stems from a real being through an operation conceived to be possible, without being real itself, since the creative operation (*energeia*) has not actually taken place and may never do so. Or we may say that a being is potential because, real in itself, it may develop unexpected possibilities, powers (δυνάμεις) or capacities (ἕξεις) which *could* be realized in certain circumstances not at present obtaining. (It may be that Aristotle keeps the term τὸ δυνατόν for the first case only?) This distinction is nevertheless fundamental when we are dealing with the *parts* of an entity.

If indeed we consider an entity A of substrate $|A|$, we can imagine (essentially through a mental geometric construction) a part B whose support $|B|$ is limited in A by such a geometrical construction. For example if A is a material ruler parametrized by $-k \leq x \leq k$ on the Ox axis, I may consider the finite part $-k \leq x \leq 0$ to be part of Ox. But if this operation takes place only in my mind and is not in fact realized, then the entity I so create, B_A, (this half of a ruler) is a *potential* entity and not a real one. If, on the contrary, I *saw* through the ruler at the point $x = 0$, then the half-ruler becomes a separate entity (χωριστή), and therefore real. Hence the affirmation: "Entelechy separates" of Met Z [2], where we again find the example of a point separating a straight line into two halves of a straight line (the point then being the actual trace of the point or awl, στιγμή). This theory of parts *in posse* or *in actu* brings

us to the definition of *homoeomerous* parts (quotation [3]). Here the continuous character (συνεχές) of the substrate comes in.

D. Homoeomerous parts

An entity *H* is said to be *homoeomerous* if every part *c* of *H* is considered to be semantically (in other words phenomenologically) equivalent to *H*. *Quantitatively*, *c* is of course less than *H*, but as far as *qualities* (ποιόν) are concerned, they are equivalent. It is the same as saying that *H* has an apparently homogeneous substrate. Water, oil, blood, fat, and bone (internally) are all homoeomerous.

All non-homoeomerous entities are called *anhomoeomerous*. The substrate of such an entity presents qualitative discontinuities: it has a form, a *situs partium*, whereas homoeomerous parts are intrinsically "formless". We observe, nevertheless, that if the support *c* is of non-trivial topology (if it is not contractile), then difficulties may arise. For example, Aristotle qualifies as "homoeomerous" a specifically localized material homogeneous component (vein, intestine, etc.) as well as the "local phenomenological quality" characterizing homoeomerous parts (thus the elements, earth, water, air... are homoeomerous, with no form or localization of their own). In the modelization of animal organization presented in Chapter 5, section B, homoeomerous parts are *strata* which may have a form and a topology. Quotation [4] shows that Aristotle was aware of the difficulty. But as he rejected the notion of space, he could not formalize the difference. The "local quality" of a homoeomerous part is a quiddity, a *logos* (quotation [5]).

Where sets are concerned Aristotle distinguishes between totality (πᾶν) and whole (ὅλον); homoeomerous parts make up a totality, but a whole like a living body has "canonical parts" separated by well-defined surfaces which give it its form. The catastrophic set is an indispensable support of form (μορφή). The parts of the entity in actuality are limited by anhomoeomerous parts. (From this we have deduced in Chapter 5, section B, justification of Geoffroy Saint-Hilaire's principle concerning the unity of the composition plan.)

There is, then, an inferior form of existence, that of homoeomerous substances. Lacking form, often immobile, they have nevertheless a *logos* that Aristotle describes as hard to define [5]. This *logos*, though of a logical nature, would now be defined as the "internal structure of matter"; it is a mixture of elements (cf. quotation [6], where matter is defined by the notion ὕλη τοῦ λόγου). It is a case of (τὸ τί ἦν εἶναι, "quiddity" (the "genetic legacy"?).

E. Homoeomerous, anhomoeomerous and catastrophe theory

Whatever the case, if Y designates the space of "internal local states" of matter, the "state" of an entity A, with representative $|A|$, could be defined by a section $\sigma : |A| \to Y$ of the fiber map $|A| \times Y \to A$. For a homoeomerous part, this section is continuous; for an anhomoeomerous part, it is discontinuous on a set K of "catastrophe points"; this set K defines the morphological organization of the entity A (every actual part of A has its boundary in K).

Whenever there is an internal dynamic defined in the support of an entity, the section σ is endowed with a dynamical principle inherited from the dynamical systems both of Y and of its support X. Catastrophe sets are where the homoeomerous *logoi* adhering to the catastrophe point in question interact; they there undergo, in Y, transformations defined by functional dynamic interaction which we shall describe later on. That is something clearly perceived by Aristotle (quotation [3]): homoeomerous parts carry *dunameis*, properties, and in this sense they are potential, their potentiality being realized, becoming actuality, in the anhomoeomerous parts which are the seats of work and activity (ἔργα καὶ πράξεις). In the case of the joint between two adjacent bones, we have a conflict between two "loci", each attached to one of the bones, the locus attached to θ_2 varying by rotation in the frame attached to θ_1. The surface of articulation is the corresponding anhomoeomerous part, coming into play in the two opposite movements of flexion and extension. In all these cases, then, there is a *localization* of actuality on a contact surface. In the same way the lung is an anhomoeomerous interface between air and blood. Such is the most simple, prototypical, situation in the "actual" interaction of two entities.

F. Axioms of actuality

I. All non-natural transformations $(A,\alpha) \to (A,\beta)$ require the presence of at least one different entity (the *mover*) M (τὸ κινοῦν), which comes into *contact* with A. M then transmits a secondary entity to A, a "species" (εἶδος) which modifies its state (cf. note 8: in our terminology this is a pregnance).

II. Any actual state can be described verbally by a nuclear sentence (with only one verb). This means that building a theory of the *act* amounts to building a theory of the *verb* as part of discourse.

REMARK. Some natural transformations are set in motion by contact with an outside entity usually considered not as an *agent* but as a *patient*. Thus coming upon a likely prey will trigger predation in the hungry predator. This is an effect of the subject's state of privation (στερητικη διαθέσις).

Ever since L. Tesnière (5) we have known that a nuclear sentence is always associated with a *verb V*. This verb is normally associated with 0, 1, 2 or 3 actants, their number being what L. Tesnière called the "valence" of the verb.

1) ZERO-VALENT SENTENCES. Zero-valent sentences, of the "It is raining" type, were apparently never considered by Aristotle. Perhaps he would not have granted them the status of "actuality" (always compositite according to him), yet he could hardly have denied them a supporting role for the *logos apophanticos*, that is, for an expression which can be true or false. Possibly this omission can be explained by the periphrastic use of the classical Greek *Zeus uei* [Zeus rains]; in any case one would be hard put to it to tell what kind of substance could have "It is raining" as an attribute. Indeed, Aristotle's philosophy requires there to be a certain permanency in the substrate of an entity, and when this substrate renews itself, like Heraclitus' river, the Aristotelian vision of substance is in deep water. (Is it the water or the bed that is the substrate of a river? (6))

2) UNI-VALENT SENTENCES. These are sentences of the NP type (Noun-Predicate). The predicate may be introduced by a copula (The sky is blue) or it may consist of an "intransitive" verb. In whichever case it is a matter of capturing the image of the section $\sigma : U \to G$ in the space of a genus G by means of dynamics internal to G (leading to an attracting minimum).

We shall suppose that with every genus—secondary entity—will be associated a substrate G, and in this space we shall have a space of quality (internal state), usually $\mathbf{R}$, as in the case of opposites (hot-cold). Then G is defined as the reunion of the basins of potential $V : G \to \mathbf{R}$; the basin of a minimum is the substrate of a species (*eidos*). On the continuous space of color impressions, for instance (a three-dimensional space $\mathbf{R}^3_+$ according to the classical theory), the adjective "blue" would be defined by a basin b, with boundary ∂b. The meaning of a predicative sentence like "The sky is blue" can thus be geometrized. The substrate

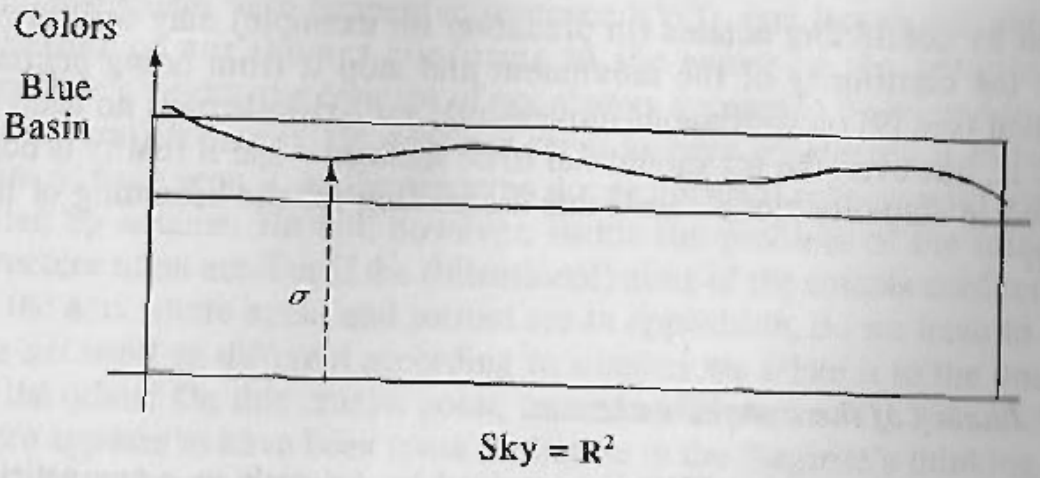


Figure 6.2 The sky is blue: *predication* as an interlinking of subject and predicate

of the "sky" is a heavenly semi-vault D^2; as far as color is concerned, the state of the sky is defined by a section $\sigma : D^2 \to \mathbf{R}^3 \times D^2$ of the morphism $\mathbf{R}^3 \times D^2 \to D^2$. The "sky is blue" is the actuality signifying that this section is "captured" by the basin b; in other words, the section $s : D^2 \to G$ is entirely contained in the tube $b \times D$, with the boundary of which ($\partial b \times D$) it is "interlinked". The ancients, who designated by συμπλοκή (interlinking) the relationship between a substance and its predicate, had little idea of how truly realist their geometrical metaphor was (Figure 6.2)!

3) DIVALENT SENTENCES. Here we have the transitive sentence SVO: an agent acts upon a patient which suffers the action. Aristotle views this kind of sentence on the collision model; the mobile body (agent or mover) moves, by impact, the immobile one (*patient* or *moved body*). We shall come back to this case in greater detail in sections G and H.

Transitive sentences involving the coming to be or the passing away of an actant demand a special formalism. For the act then has a global topological effect on the creation or disappearance of an actant. Space G is then the usual space $\mathbf{R}^3$ (the common substrate space), and on G, taken as an internal space, we have a cusp catastrophe with control space $\mathbf{R}^2$ (*Ouv*). Here the "irenic" character of Aristotelian philosophy comes in; once the act is set in motion, it has to be accomplished—unless it is prevented from so doing (ἄν μή τι ἐμποδίζῃ). Apparently there is no theory of conflict to be found in Aristotle (7). Initiatives

taken by conflicting actants (in predation for example) may well interrupt the continuity of the movement and stop it from being accomplished (see [9] on *continuous* movement), yet Aristotle pays no heed to this. If, however, the act should fail to be realized—and if reality is contained in actuality alone—isn't this disquieting for the becoming of the real?

G. Theory of the transitive act

The transitive sentence SVO is perceived by Aristotle as a competition between species within a genus [8]. In the space of genus G, the *images* $\sigma(|S|)$, $\sigma(|O|)$ of the entities S, O are subject to fiber dynamics which will realize the *telos* of the act. Paradigmatically, Aristotle sees in this a harmonization of opposites; confrontation will, more often than not, be appeased by the working out of a solution of compromise.

TYPICAL EXAMPLE (a modern one!). "The mother warms the child". Contact between the mother's warm body and the child's cold one will tend to equalize their temperatures; the child's body cools the mother's by "anticinesis" (ἀντικινεῖν) and we move towards the final thermal equilibrium. In the case of visual perception, the same process of equilibration between an outside stimulus (an intermediary (μεταξύ)) and a sensitive apparatus in a state of *potentiality* and therefore of total availability, leads to a faithful copy of the object perceived by the *nous pathèticos* [10].

Aristotle was not specifically interested in trivalent verbal patterns (or quadrivalent messenger patterns). However he does mention cases (πτώσεις) as playing a part in the organization of an act [15]. He would probably have agreed that, in the last analysis, every complex act can be described by a concatenation of bivalent acts (as imposed by the genericity, i.e. the naturalness, of the underlying process). It is therefore useful to describe the structure of the general divalent act.

H. The act, the actants, and their telos

If we accept the fact that there is no act that does not imply a primary entity, it is reasonable to wonder whether the act has a *telos*, and whether this *telos* is also that of one of the beings involved in the act ("actants" as they are called in modern linguistics). In acts associated

with a *divalent* verb (transitive sentence SVO), one has to ask oneself whether or not the act conforms to the *nature* of the actants. In Aristotle's works, the concept of *act* always appears to be related to one (or several) actant(s). He does not seem to have considered it in isolation, to have seen it, as the moderns do, as a *formal* schema with places filled by actants. He did, however, tackle the problem of the internal structure of an act. For if the (intentional) aims of the actants conflict, as in the acts where agent and patient are in opposition, do we have to see the *act* itself as different according to whether we relate it to the one or to the other? On this crucial point, treated at lenght in *Φ*III 202a and b, there appears to have been *some hesitation* in the Stagirite's thinking. In the end, however, he opted for the *unicity* of the act: Ἀλλὰ μία ἔσται ἡ ἐνέργεια! (The actualization will be one; *Φ*III 202a, 36).

At the same time he had to give up the idea of attributing a definite *telos* to the act—whence perhaps the expression *energeia atelès* used to describe the process of *motion* whereby actualization is accomplished. But the *telos of* the act does not necessarily have to be taken in a temporal sense; it could be more abstract. In the example of the point *O* dividing the axis *Ox* into two halves of a straight line (quotations [2] and [11]), we can already see that the mark of the point has the effect of *separating* the two halves. The geometrical *form* of the point *O* on *OX separates* the two half-lines. Thus the logical *eidos* of separation (χωρίζειν) cannot be dissociated from the topological presence of the point, and this correspondence is timeless. In the same way, in Aristotle's example (quotation [12]) "The road from Thebes to Athens and the road from Athens to Thebes are the same", it may be said that the *telos of* the road is the connection of the two cities *in abstracto*, the direction of the route remaining unspecified. Only by considering the actant, through the injection of time experienced by the subject into this timeless structure, will it be possible to say what the *direction* of the action is.

Underlying the intentional *telos* of the actants, then, there would appear to be a *telos* which is *outside time*, morphological in fact, which catastrophe formalism alone is in a position to define. This would be the organizing center of a singularity unfolding in a control space of purely geometrical significance. For example in the bifurcation fork $x^4 - ux^2$, the road from Athens to Thebes would be the splitting of a "milestone" O situated halfway between the two cities. The paths *of* the actants to which a direction associated *with* the *telos* of the "subjectivized" act is given emerge from the unfolding of this singularity. In this sense we may speak of *tertiary entities*, classifying by analogy certain types of actions belonging to isomorphic actantial schemata.

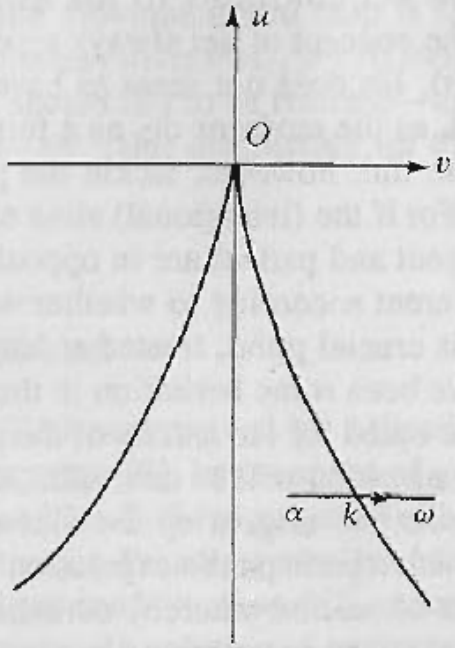


Figure 6.3 Capture catastrophe. Representative segment

I. Genesis and death

Those acts which imply the coming into being and disappearance of an actant have a special status. For example, the capture of prey by a predator, represented by the diagram —⌒— is topologically isomorphic to the emission of an actant "begotten by" a parent —⌐— . Only the time arrow distinguishes one morphology from the other, and here the time arrow is to be found in the meaning of the verb. We know how the pattern of capture is represented in catastrophe formalism by an oriented segment $\alpha I \omega$ transversal at a point k to the bifurcation curve $4u^3 + 27v^2 = 0$ associated with the cusp catastrophe (Figure 6.3).

In theory, emission could be obtained (see Thom *SSM*, page 312) by inversing the direction of the segment. In actual fact, having to cross a potential barrier would mean having to make a detour through the organizing center (or its neighborhood): capture is "thermodynamically" easier than emission. This cusp schema is thus the non-temporal basis of the catastrophes of genesis and disappearance.

It would be interesting to know whether the Aristotelian corpus contains an example where for two beings X and Y involved in the same actualization, a common syntagma is to be found of the type (X καὶ Y ἐνεργεῖα): X and Y *in actu*. A divalent structure always implies an act-

ant and a patient. According to quotation [13], the agent is in a state of *energeia*. As subject, the actant is in the nominative; the patient is in the accusative and, with respect to the act, in a state of *entelechia* (ἐντελέχειᾳ), said to be ατελής, perhaps because the aim of the action does not conform to the patient's own *telos*, involved as he is in an action imposed from without which may be a regrettable accident from his point of view. See note 8 on the distinction (much discussed among specialists) between *energeia* and *entelechia*.

In bivalent interaction, both actants belong, as Aristotle profoundly remarked in *De Generatione et Corruptione* (quotations [14] and [8]), to a common genus but different species (like hot and cold on the temperature axis in the example given above). In the case of death by capture the common genus is our usual space; the minima basins are the actants' substrates. There are then in the potential control space *typical dynamics* which carry the meaning of the verb. These dynamics are like attractive "rivers" realizing "chreods"(9) in the substrate space. In the case of thermodynamic equilibrium, this would be a return to the organizing center: the passage from two single roots to one double root. There is available no real in-depth analysis of these dynamical principles. In situations of conflict such as predation in higher animals global behavior belongs to game theory. Taking predation as an example, we have a zone of bimodality in the cusp plane, where each actant is trying to impose his own dynamic (Figure 6.3). The predator *P*, for instance, will so move as to cause the system to follow the attracting path (corresponding to the *telos* of capture) $\alpha K\omega$. The prey *p* (if it has recognized the predator as such) will on the contrary strive to keep the whole system away from the critical curve $OK(c)$ along which capture takes place and to bring it back towards the half-plane $v < 0$ where only the prey-actant *p* subsists, in order to escape the predator (Figure 6.4). The whole process, being conflictual, is unforeseeable; and its outcome is, in principle, contingent.

Thus the merit of catastrophe formalism lies in associating with every set of topologically equivalent acts a unique formal schema outside time that takes the opposing aims of the actants into account and throws the description of their behavior back into a dynamical system, itself ill-determined, on the control space.

J. Contingency of the act

In the conflictual actuality involving two actants, potentiality (δύναμις) is manifest in the tactical initiatives of the actant players, so leading to discontinuity in their respective movements and in the global movement of the system. So we are a long way from the continuous progression

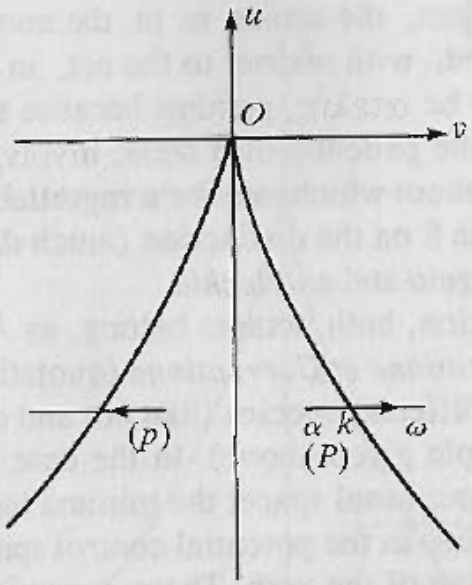


Figure 6.4 Predator-prey conflict. Segments representing actantial strategies

(συνεχής) of motion described in quotation [9]. Let us, moreover, recall at this point that the Aristotelian adjective "συνεχής" covers three modern mathematical notions: continuity, connectedness and the monotony of function. Whence a certain haziness as to the internal structure of an act and the resulting situation.

The preceding examples are almost exclusively concerned with the processes I have called archetypal in *SSM* because of their intrinsic simplicity: there is a direct relation between their signification and their morphology. But what of complex acts, those involving qualities for example? It will be observed that there may be a hierarchy of secondary entities $G_1 \rightarrow G_2 \rightarrow \ldots \rightarrow G_\infty$, G_∞ the supreme genus (10). Corresponding genus spaces are then fibrated. If G_i is a species of genus G_{i+1}, then the substrate of G_i is in the space of the state of G_{i+1} as basin of a potential minimum for example. But it is doubtful whether such a hierarchy can go much further: the *categories* intervene as universal operators of the subdivision of a genus into species, and they cannot be iterated. What makes for the internal complexity of certain actualizations is the use of a whole hierarchy of instruments. In order to aim at a target $\hat{T}$, one may have to start by aiming at a preliminary target T_1, the means of attaining $\hat{T}$, then T_2 as the means of attaining T_1, and so forth. Thus one can see how it would be possible to construct a graph of auxiliary targets

sometimes involving several targets for the simultaneous realization of one and the same effect (συναιτία). Indeed, grammar as we have seen takes into account the use of action-furthering instruments in tri- or quadrivalent verbs. We are reminded that Aristotle mentioned cases (πτώσεις), in his *Categories*, as being "categorial" descriptions of predication.

K. Examples of complex acts

1) HOUSEBUILDING. We shall be looking at two examples that are clearly more complex: the building of a house and the development of an embryo. A rough schema of house-building includes the following stages: choice of a piece of land, general design of the building, setting-up of financial resources, determination of the main guiding gradients (the vertical (imposed), orientation and depth), selection and delivery of materials (bricks, tiles, mortar, timber for beams, etc.), digging and cementing the foundations, raising the walls, putting the beams in place, reaching the top, roofing-in, and fitting up the interior by installing water and electricity. The process can be depicted by the graph in Figure 6.5.

Note that whereas the act of foundation separates, the attainment of an auxiliary goal, on the contrary, often requires connecting acts (joining beams by means of a tenon, bricklaying, etc.).

At the start we have a great many auxiliary divisions, for example, the cutting of bricks before firing, the shaping of wood for beams and rafters. Then the construction will require a host of junctions; brick to wall, beam to beam, rafter to beam, tiles to rafter, and so on. All this to end with a "space" separated from the outside air by watertight walls and roof (albeit pierced by doors and windows). Because the building of a house fulfills deep down in man a persistent biological longing for the invertebrate's *exoskeleton*. The house is to be seen as a "blister" on the earth's surface, a "pocket of compromise" between air and earth, extruded from the soil, the earth-air interface.

In hydrodynamics a shock received by a liquid can cause a bubble, a continuous figure formed by liquid walls joined up together. The building program is a simplified approximation of this continuous figure, this *bubble* (all but realized, moreover, in our modern inflatable structures). First defined according to *directive gradients*, the figure is then mentally decomposed into elements of volume, surface and length satisfying the technical norms envisaged. It is subsequently put together again by synthesis of these elements (Figure 6.5).

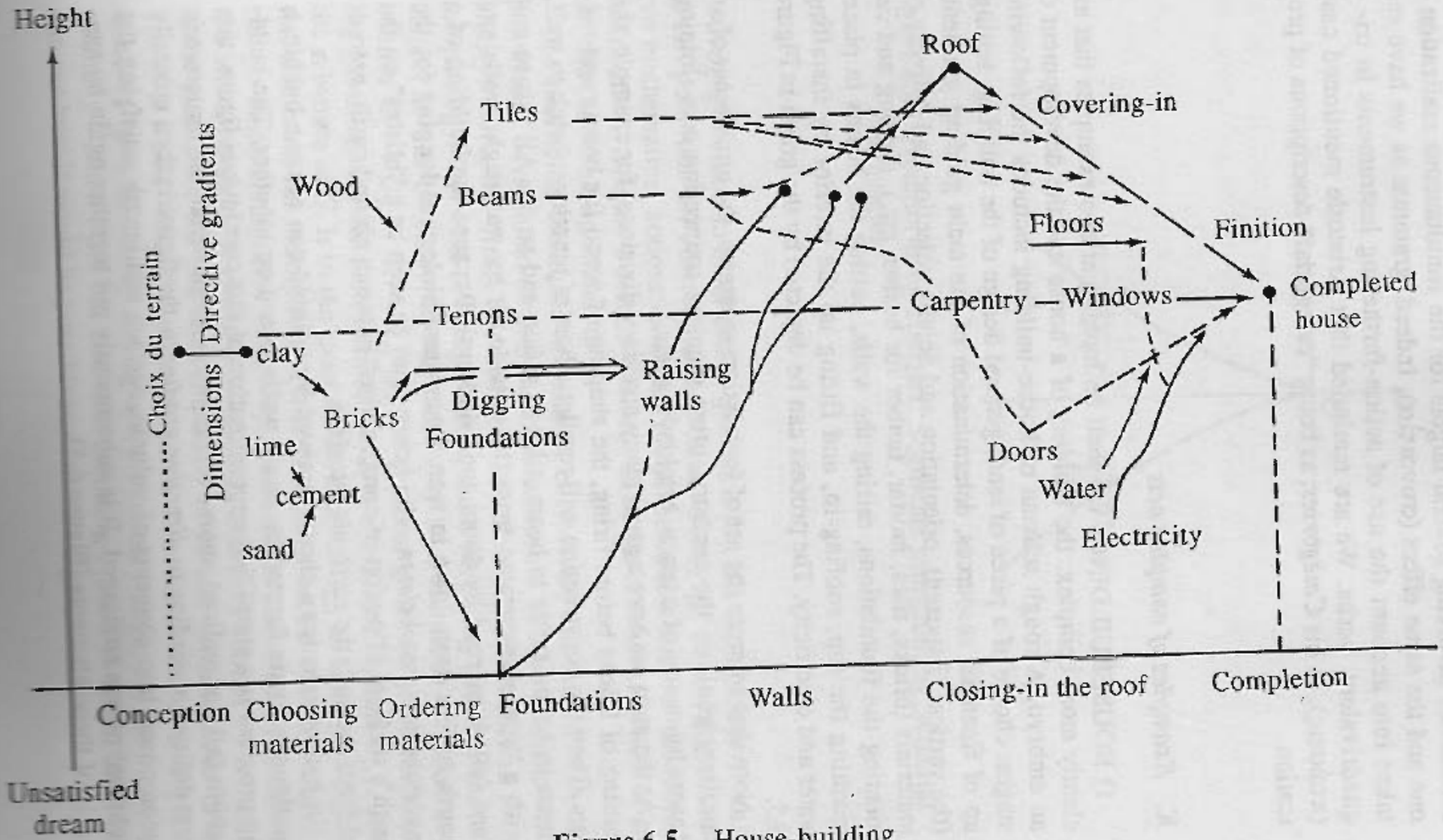


Figure 6.5 House-building

There is no mystery in this particular morphogenesis because of the presence of a permanent "motor", the mental image of the project in the architect's mind. The other example is rather different.

2) EMBRYOLOGY. Figure 6.6 shows the "epigenetic landscape" of the embryology of a (generic) vertebrate. As in house-building, different stages can be recognized: conception (i.e. fertilization of the ovum by the spermatozoon); primitive scission period (blastula stage); establishment of directive gradients (the animal-vegetal gradient stemming from oogenesis, the anterior-posterior gradient, and the left-right gradient, the first given by the meridian plane of spermatozoon injection, or by an epigenetic mechanism). Next, materials are synthesized (by synthesis of messenger RNA and liberation of the corresponding genes). Then comes formation of the main germ layers (ectoderm, endoderm, mesoderm—the gastrula stage), followed by neurulation and elongation of the embryo, and, after that, organogenesis through layer synthesis (epithelium and mesenchyma). Finally the organs are initiated, beginning with the heart, from which the vascular system is constituted, followed by the nerve explosion resulting in the innervation of the organs, and, lastly, the maturation of functional activities.

Figure 6.6, in which all these data are synthesized, fully justifies Aristotle's reference to the Orphic metaphor comparing the constitution of an organism to the making of a fishing net (quotations [16] and [17]).

The text between these two quotations from *De Generatione Animalium* brings out both the quandary and the extraordinary penetration of Aristotle in his study of the mechanisms of embryology. He alludes to the automatism with which movements and syntheses of organic matter succeed each other (something which should appeal to the moderns) and goes on to discuss the presence of a permanent "motory" entity, coming from seed and different from the organism (whose existence he finally denies). Last but not least, Aristotle brings in by analogy the abstract idea of architecture present in the construction and programming of organogenesis (quotation [17]). Something here is apparently at variance with Aristotle's basically materialistic philosophy: Platonic Ideas do not exist, yet there must be something like an Idea to direct this whole set-up.

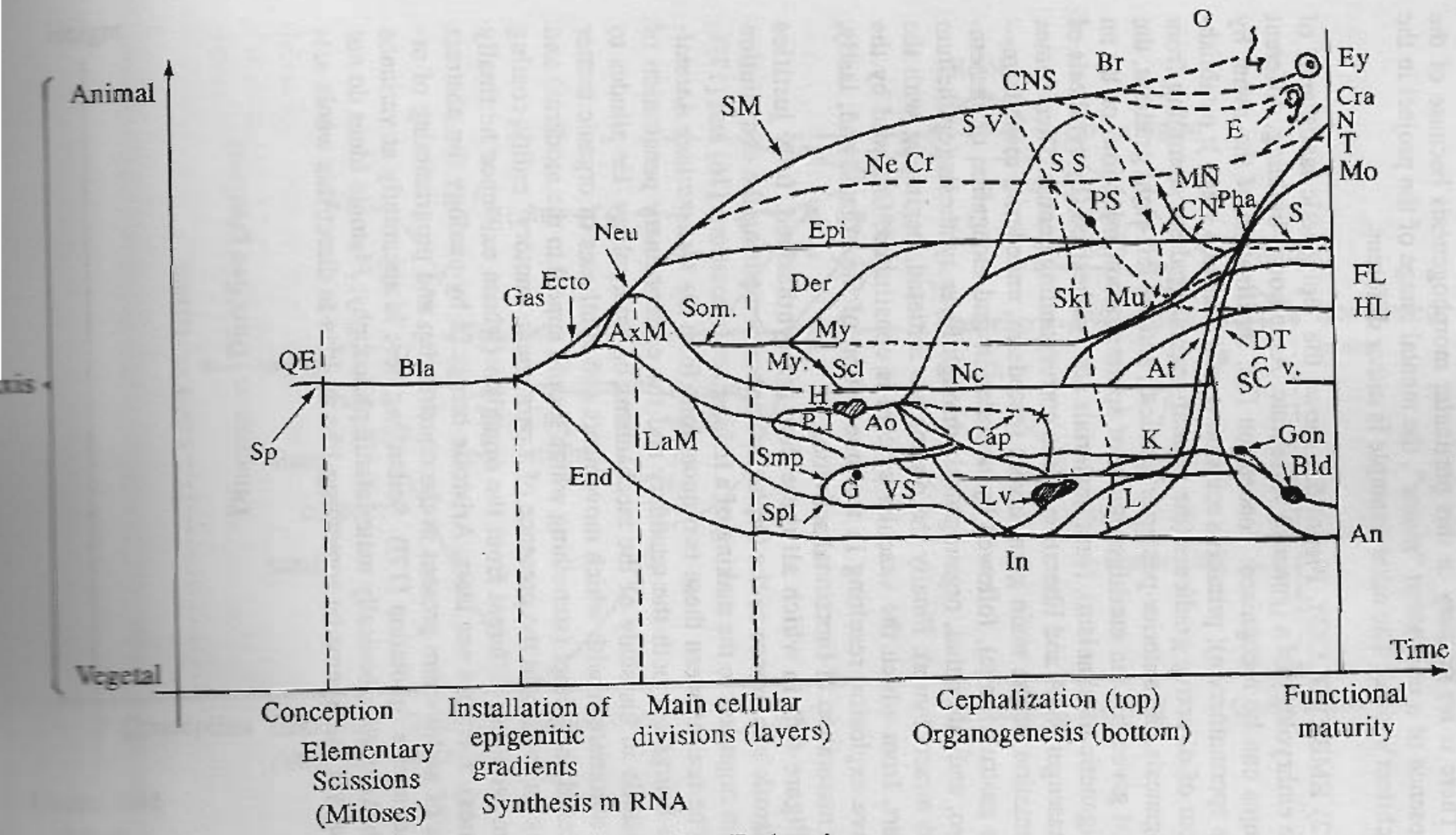


Figure 6.6 Embryology.

An	Anus
Ao	Aorta
AT	Arterial trachea
AxM	Axial mesoderm
Bla	Blastula
Bld	Bladder
Br	Brain
Cap	Capillaries
CN	Coenesthetic nerves
CNS	Central nervous system
Cr	Cranium
Der	Dermatome
DT	Digestive tube
E	Ear
Ect	Ectoderm
End	Endoderm
Epi	Epidermis
Ey	Eyes
FL	Forelimbs
Gas	Gastrula
Gon	Gonad
H	Heart
HL	Hind limbs
IP	Intermediary part
In	Intestine
K	Kidney
L	Lung
LaM	Lateral mesoderm
Lv	Liver
M	Mesoderm
MN	Motory nerves
Mo	Mouth
Mu	Muscles
My	Myotome
N	Nose
Neu	Neurulation
Ne c	Neural crest
Nc	Notochord
O	Olfaction
Pha	Pharynx
PS	Parasympathetic system
QE	Quiescent egg
S	Skin
SC	Spinal column
Scl	Sclerotome
Skt	Skeleton
SM	Spinal marrow
Smp	Somatopleure
Som	Somites
Sp	Sperm
Spl	Splanchnopleure
SS	Sympathetic system
T	Teeth
VS	Vegetative system

Here is the model I would propose to fill in this blank. The dynamical system of the quiescent egg is reduced to a punctual attractor. After fertilization, a great number of enzymatic cycles are unleashed, whence the formation of an attractor of large dimensions in the blastula stage. This attractor will then implode according to the modalities spatially parametrized by epigenetic gradients, resulting in the figure of the physiological blastula described in Chapter 5, section F. These localized implosions will separate the layers, but local syntheses will then follow, allowing the reconstruction of the initial global figure. Here it is the form of the metabolism and its variations that bring about morphogenesis. In both instances we have an initial impetus creating a continuous figure: blister or bubble in the case of the house; in that of embryology a schematized organism in the space of metabolic activities. But this ini-

tial élan comes up against directive gradients which deform it and "cultural constraints" which give specific character to the materials in their elementary forms. In biology, there are the mitoses which produce the blastula; then the genes that determine which proteins are to be synthesized, then the splitting-up into main layers (ectoderm, mesoderm, endoderm). Afterwards we have the period of putting-together, the operations of synthesis. These operations have their origin in an essential factor, the global form of the metabolism, already there in the blastula and subsequently differentiating into spatially localized organs. But in fact, for a comprehensive theory, we should consider the full circular structure, the original hen and egg cycle.

The distinction of the homoeomerous parts of an organism is no different from the stratification considered in Chapter 5, section B. The definition of anhomoeomerous parts, on the contrary, is a delicate matter, for exactly what constitutes the individuality of such a part remains mysterious as there is not always an obvious functional interpretation. This question is dealt with in Chapter 7, section C.

I would like to end here with a remark concerning the distinction between acts of division (scission) and of binding together (reunion), in house-building as well as in embryology. This distinction can be likened to the classification of singularities of the stratified map $\sigma \circ \psi$ defined in Chapter 5, section E. Scissions are typically additive singularities (creation of a new homoeomerous stratum for example); uniting acts are subtractive singularities. This dialectic between scission and reunion most certainly has a topological root. Every entity that is actuality, being "separated", requires a boundary-form (serving as its *eidos*, see Chapter 7, section B); it rests then on a "cycle" in the homological sense. In the same way, every action also needs something resembling a cycle, for there is always a time-sequence of the form rest $\rightarrow$ active state $\rightarrow$ rest. Insofar as a created entity is individuated, it has to admit the construction of a boundary. If we are talking about a sphere, Morse theory relations will impose near-equality between points of odd index (scissions) and of even index (reunions). One might also wonder whether the instrumental entities initially divided by the constructor (like bricks cut in clay), being the first to come into the process, are then, as in quotation [24], "posterior" entities by their nature, or essence. They are, indeed, derived from ritualization, from a long cultural past. Are we to conclude that the axiom of quotation [24] can be applied only to processes that are the fruits of a long past, in other words that there is no such thing as genesis as a physical phenomenon, in the modern understanding of the term?

NOTES AND REFERENCES

(1) This set of axioms does not aim to confer on Aristotle's physics a logical coherence it doubtless does not claim. It aims to help the modern reader of post-Galilean scientific formation to enter more easily into the Aristotelian system.

(2) The sublunar world. The heavenly world has a particular status (stars animated by a uniform circular movement) which we will not go into here.

(3) See the appendix at the end for discussion about these substrate properties.

(4) There is much debate among Aristotelians as to whether the parts of an οὐσία are οὐσίαι. The problem is particularly thorny when it concerns animal parts, and Aristotle himself does not appear to have a clear opinion on the issue. Quotation [20] seems to show that any acceptable part of a primary entity should be three-dimensional. If this is so, then the axiom of separability IV should give to the intersection of two entities (necessarily two-dimensional at most) an ontological status of inferior dignity. We did not wish to enter here into distinctions of the sort, implicit in the expression "in general" (ὡς ἐπὶ τὸ πολυ) of the axiom of locality V.

(5) Lucien Tesnière, *Eléments de syntaxe structurale*, Klinksieck, Paris, 1959.

(6) For a Platonist there is no problem in the permanency of Heraclitus' river. The river will be defined by geometrical interfaces: earth-water (the river-bed), water-air (surface of the river), and the triple junction of earth-water-air (the river banks).

(7) Modern theorists of the suspect will doubtless attribute these irenic dispositions to Aristotle's privileged relations with the powerful of the day; why dwell on conflict when every member of the community must be expected to comply with the natural demands (φυσικαί) of the social or universal order?

(8) **On the use of** ἐνέργεια and ἐντελέχεια. The fact that Aristotle is far from systematically observing the distinction drawn in quotation [13] between the mover in a state of *energeia* and the moved in a state of *entelechy* has led many commentators to argue that a clear difference in meaning between the two words can scarcely be made. In quotation

[12], for example, the teacher as well as the taught is said to be in ἐντελέχεια. I believe there is above all a case for making an *aspectual* (in the linguistic sense of the word) distinction between the two terms. There is indeed a verb ἐνεργεῖν (to act) in absolute use, whereas there is no verb such as ἐντελεχεῖν. As a result, ἐνέργεια, derived from the verb ἐνεργεῖν, has a *durative* aspect implying a certain duration of the process. Ἐντελέχεια, on the contrary, concerns those two instants, crucial for both agent and patient—the beginning (ἀρχή) of motion, when a project is conceived, and the completion (τέλος) of the project itself. So Ἐνέργεια is used more with respect to the duration of the act in time |——| and Ἐντελέχεια with respect to the two extremities, conception and achievement, which in fact constitute formally isomorphic objects (the aim of the act).

(9) For the term *chreod*, due to C.H. Waddington, see *SSM* p. 114. We are reminded, by the concept of chreod, of Waddington's *homoeorhesis* and the "rivers" of F. and M. Diener (see Chapter 3, note 5).

(10) We refer to the "hypergenera" introduced in Chapter 8, section C. This hierarchy of hypergenera is unknown; actually it is a question here of the determination of the Porphyrian tree (Chapter 8, section F), the object of ontology. From this point of view, the evocation of categories in the text does not seem justified, for categories are the universal operators of all predication (a system of universal operators on the differences), but they have nothing to say on the "substrates" which determine the structure of Porphyry's tree.

(11) In *SSM*, the formation of a "pocket of compromise" is related to the "butterfly" singularity. *Loc. cit.* p. 73.

CHAPTER 7

PERSPECTIVES IN ARISTOTELIAN BIOLOGY

A. *The primordial topological intuitions of Aristotelianism: Aristotle and the continuum*

We shall present here those intuitions which we believe sub-tend all Aristotelianism. They are ideas that are never explicitly developed by the author, but which—to my mind—are the framework of the whole architecture of his system. We come across these ideas formulated "by the way" as it were, condensed into a few small sentences that light up the whole corpus with their bright concision. We will need to go back to the Platonic origins of Aristotelianism; we will try to understand the divergence between Aristotle and the Academy, the reason for his rebellion against the parent doctrine. The pair of opposites matter-form—which is the *first* thing that comes to mind—is not strictly an original idea of Aristotle's. It must certainly have existed in a similar form in the Platonism of the later Academy, known as the Academy of unwritten teachings (ἄγραφα δόγματα).

One would doubtless not be wrong in identifying Aristotle's criticism of the theory of Platonic Ideas as a new standpoint. But the importance given to *matter*, necessary support of all actuality, is probably not the decisive innovation; more important was perhaps Aristotle's deliberate opposition to the "numerology", inherited from Pythagorism, that reigned in the later Academy (an example of which can be seen in Xenocrates' theory of the soul as a "self-moving number", criticized in *De Anima*) (1). Everyone knows how much the question of Aristotle's relations with the Academy remains obscure and controversial (2). It is my hope to contribute some elements involving aspects not easily appreciated by specialists for whom the problem of the relationship between

CONCLUSION

A. *Aristotle and modern Science*

The time has come to end our Aristotelian detour. Some readers may be surprised that I should set such store by doctrines long since considered out of date. But I believe that Aristotle's approach remains singularly relevant in the biological domain, where it holds riches as yet unexploited. It is no doubt otherwise for physics in the modern sense of the term. If one wished to mark the crucial spot where modern science parted company from Aristotle, one would find it in the example of the stone thrown up into the air and falling back to earth. In Aristotelian physics, there are two continuous movements, consecutive but distinct: the forced upward movement (βίαιος) followed by the natural downward movement. At the highest point, where the movement changes direction, there is *discontinuity*. For us, after Galileo, there is one single movement described by a single parabolic law of the form $z = z_0 - [1]/[2]\ gt^2$ (where z is the height and t the time). The rising motion is analytically continued in the falling motion. So between Aristotle and Galileo we have *changed our criterion of individuation*. Instead of considering the instantaneous target (cf. Chapter 6, section C, the *energeia* of being in the potential state, as such, or the final setting), we have adopted the purely mathematical definition of the analytical curve. It is, of course, important to consider the direction of the movement when one wishes to describe the process qualitatively. But we really want to define the individuality of a process—as only mathematics can do. Our quantitative physics rests in its entirety on the use of analytical objects (Lie groups, for example) and of analytic continuation. The miracle of physics is that this should be successful (1). But there should be no extrapolation of the miracle outside its proper domain (that of fundamental laws describing the infinitely great and the infinitely small brought somewhat curiously together).

It is a fact that Aristotle would not have known how to quantify a simple mechanical phenomenon like collision. But we must give him the credit for having, apparently for the first time in the history of humanity, offered the quantitative formulation of a physical law: the law $E = FT$, "The space covered by a moving body under the action of a force F is proportional to the product of the force F by the time of the action T." An erroneous law, it is true, but not so very false after all in our sublunar world. And what does a mistake like this matter as against the conceptual universe opened up by this innovation? His inability to conceive how bodies react in collision leads Aristotle to admit a generalized contingency in our world. Living beings can move themselves spontaneously. As for inanimate beings (ἄψυχα), their motion is governed by the attraction of natural loci or by reciprocal interaction when they meet. This is the domain of the αὐτομάτον—efficient causality without a target. Our author is none too clear here when it is a question of determining the ultimate causes of movement. It is obvious that forced movements exist in inanimate entities. Statistically at least, they can be imputed to impulses due to the sun's movement on the ecliptic or, in the last resort, to the unmoved mover, God.

This unforeseeable nature of natural phenomena, which he describes as contingency, does not necessarily signify that Aristotle would not have accepted a certain determinism of such processes. On the contrary, mechanical causality is often mentioned in the corpus as something inevitable (cf. what is said about the causal mechanisms of generation in embryology). I feel that Aristotle would have allowed the existence of local formal causality applied to these sequences of collisions and interactions (2). But, from a human point of view, these phenomena can be considered as resulting from *chance* in the sense given to the word by A. Cournot, two thousand years later. (Aristotle's commentators are divided on this point: some are for a contingency intrinsic to the world, others for a contingency relative to man which can (sometimes) be controlled (Mansion) (3).) However that may be, it is not on this last point that the moderns would pick a quarrel with Aristotle. The chief objection made to Aristotelian doctrine concerns the question of final causes. I believe that we have been unfair to the Stagirite in this. It must be realized that a strictly final cause, i.e. a cause strictly posterior to its effect, raises almost insuperable problems of intelligibility. Indeed—as we have seen with objective pregnances—causality is always thought of in science as resulting from the transport of invisible but efficient entities that come from the cause and bring about the appearance of an effect. If such a relationship exists between an effect E_0 at an instant t_0, and a cause C_1 at an instant $t_1 > t_0$ and if this causality is realized by efficient transport of

entities between C_1 and E_0 going backwards in time, then there are two cases to consider:

Either: The human experimenter has no way of acting on this transport, of stopping or of disturbing it.

Or: He *is* able to stop this transport, for instance by erecting a wall impermeable to the efficient entities between E_0 and C_1.

The first possibility is admitted in Quantum Mechanics by certain physicists (Costa de Beauregard) (4), but is rejected by most. The second would imply, by application of the saying *Sublata causa tollitur effectus*, that the effect E_0 can be destroyed by erecting a barrier between E_0 and C_1 at an instant τ such that $t_0 < \tau < t_1$. In other words the experimenter would be able to intervene in his own past, something very difficult to accept. In what we believe to be Aristotle's conception of the act, the aim of the act (its *telos*) is the organizing center of a process that may be considered as a morphogenetic field, an anhomoeomerous part of space-time, a form imposed on the future. But this validity is only qualitative (topological), and nothing can be said in general about the quantitative dimension of the domain where the model will be applied. As the Master said, ἄν μή τι ἐμποδίζῃ, if there is no hindrance. The subsequent action of an experimenter can perturb, cut short, even practically annihilate the development of a morphogenetic field. All finality is, of necessity, conditional, as is all formal causality involving the future. When this point has been understood, the supposed incompatibility between Aristotelian teleology and modern science disappears. We should remember the classical sentence from *De Generatione et Corruptione*: The active power is a cause in the sense of that from which the process originates: but the end, for the sake of which it takes place, is not active (quotation [19]). Thus, the final cause is not directly active. Just as a statue needs the sculptor for its form to come into being, so all finality demands the presence of competent entities, which, once they have entered into a state of privation, will fulfill their need by realizing the requirements of the future form (very often without being themselves aware of it!). Of course the guided character of this transformation in conformity with a shape not yet in existence would pose a thorny problem for Aristotle. He could at least reply that a material support is necessary to begin with, but not just any matter; it would require a *materia signata* carrying appropriate information—a competent terrain, embryologists would say.

The formal cause acts on space-time in a domain D by creating there an anhomoeomerous part of given form; but the extension of this do-

main D into the future depends on contextual situations which are generally difficult to describe in detail. The situation is not much different from that of classical determinism in Hamiltonian dynamics, except that in Aristotle the model is given on a local map whose real extension in our usual space-time we do not know, whereas in physics such knowledge can be had, thanks to the miracle of physics.

Much has been said about the sterility of final causes, bringing to mind Bernardin de Saint-Pierre (5). However a coherent theory of teleology which can be reduced to local formal cause is by no means trivial. It has in fact been observed that the contact (necessary for interaction) between two entities is due to an "indeterminate process *à la* Cournot" (6). This has important consequences. First of all on the structure of complex acts: if, in order to attain a target T, one has first to achieve an auxiliary instrumental target T_1, it will be necessary to make quite sure that the result of T_1 is injected into the preparation of T. Whence the need to have a strict control over nature. The archer aiming at a target relies on the naturalness of the arrow's movement in the competition between forced and natural movement. His art shows that such control is possible, manifest in the final *junction* of arrow and target. Finalized acts often present a junction morphology. Indeed it is almost a characteristic feature of theirs, in contrast to acts of foundation which, like Aristotle's entelechy, separate. The struggle again Cournot's style of indeterminism alone makes it possible to realize spatial encounters that would be considered improbable by the theory of genericity. One such is the law of cofold coincidence formulated in Chapter 3. We are all familiar with innumerable examples of tools that achieve junction: nails, needles, electric wires, radio communications, etc. Animal anatomy offers countless such realizations: muscles, nerves, vessels, etc. This is to be seen even in language; Aristotle himself observed that in the syllable *ba* there is a principle of synthesis that makes this syllable into more than just the aggregation of the two phonemes *a* and *b* (Met Z, 17, 1041b, 10–16). We find here again the distinction between animate and inanimate, in other words, the soul. Nature (φύσις) is present in the behavior of inanimate beings. But the animate being is able to exploit natural regularities in order to stabilize connections that would be accidental, not generic, in the inanimate world. So there seems to be here (in theory) a formal possibility of characterizing the living state, a problem that has baffled biologists up to now. What is so interesting about Aristotelianism is that it is a philosophy both materialist (inasmuch as it denies the possibility of a Platonic existence without matter), and finalist. An association which, we have said, has not been found since.

B. Demiurgy and Hermeneutics

We have seen, in the progress made between Aristotle and Galileo, the importance of analytic continuation as a criterion of process individuation. But analytic continuation is not a strong tool for quantitative extrapolation. In the *ε-approximation of an empirical* function $f(X)$ on [–1, +1], one can find analytical functions whose holomorphic domains present the most arbitrary variations. This means that only a pre-existing theory, based on an underlying ontology of global nature, can specify families of functions that are restricted enough to allow reliable extrapolation. Such is the case *in fundamental* physics, where the principal tool is the analyticity of the representations of Lie groups (symmetry groups) that define the geometry of our space-time. That it should work as *it* does is a miracle. Physicists have been led to adopt what I call a "demiurgic" attitude. One imagines the world to have been constructed by an intelligent Demiurge *with the help of a* few simple formulas. The aim of science is to find out what these formulas are and allow man to realize the Promethean dream of ruling the world. And this even when *the* formulas resemble magic formulas with no intelligible justification. (To be convinced of this, we have only to think of the unintelligible character of quantum *mechanics.*)

To this attitude may be opposed one that I shall call "hermeneutic." Here one is placed in the situation of the man sitting in Plato's *cavern*, watching shadows thrown by a fire on the cave wall and trying to reconstruct the real beings whose shadows are seen. To reconstitute a body in three *dimensions from its apparent* contour (7) is the special task of hermeneutics. It can lead to the manifestation of permanent entities on whose interactions qualitative or quantitative constraints bear that *one* will endeavour to specify. Observation then gives way to the kind of controlled demiurgic activity that is modelization (qualitative, or, in the best of cases, *quantitative*). *One* may also have to change the underlying ontology if that helps to make a more comprehensive, more exact and more intelligible model. A table of classification of the chief *modes of* explaining reality is given in Table C.1.

Modern science has made the mistake of foregoing all ontology by reducing *the criteria of truth* to pragmatic success. True, pragmatic success is a source of pregnance and so of signification. But this is an immediate, purely local meaning. Pragmatism, in a way, is *hardly more* than the conceptualized form of a certain return to animal nature. Positivism battened on the fear of ontological involvement. But as soon as we recognize *the existence* of others and accept a dialogue with them, we are in fact ontologically involved. Why, then, should we not accept the entities suggested to us by language? Even though we would *have to* keep *a* check on abusive hypostasis, this seems the only way to bring a

		Technical means	Discipline	Underlying Philosophy
Global object (World)	Global study	Mathematics Symmetries Groups Analytic continuation (extrapolation)	Fundamental Physics	Demiurgy
Global object (World) Earth	Local study	Observation Taxonomies Quantitative modelization (approximations)	Macroscopic physics Descriptive sciences : Geology… (Macro)-biology	
Local object	Global study	Black box Differentiable or qualitative modelization	General theory of systems Catastrophe Theory	Hermeneutics
Local study	Local object	Microscopic analysis	Molecular biology	Reductionism

Figure C.1

certain intelligibility to our environment. Only some realist metaphysics can give back meaning to *this* world of ours.

NOTES AND REFERENCES

(1) According to E.P. Wigner's well-known expression: "The Unreasonable Effectiveness of Mathematics in the Natural Sciences", *Symmetries and Reflections—Scientific Essays*, Eugene P. Wigner, MIT Press, Cambridge, MA, 1970, Chapter 4, 17, p. 222.

(2) I allude to quotation [17] from *De Generatione Animalium*. It is interesting to note that the English word "automaton", coming directly from Aristotle's αὐτοματον, gives us the strict image of a determinism completely ruling out contingency.

(3) Mansion Augustin, Ed. *Introduction à la physique aristotélicienne*, ed. Peeters, 2nd edition, Louvain-Vrin, Paris, 1946.

(4) Costa de Beauregard, *La physique moderne et les pouvoirs de l'esprit*, Le Hameau, Paris, 1980.

(5) Henri Bernardin de Saint-Pierre, "Melons are divided into sections and seem intended to be eaten by families", *Étude de la nature*, vol. 1, p. 303.

(6) Antoine Augustin Cournot, *Oeuvres complètes*, CNRS, Bibliothèque des textes philosophiques, Vrin, Paris.

(7) The mathematical aspect of the problem is dealt with in Yannick L. Kergosien's "La famille des projections orthogonales d'une surface et de ses singularités", CRAS, Paris, Tome 292, Série I, 1981, p. 929.

QUOTATIONS FROM ARISTOTLE

Abbreviations

Met	Metaphysica
Φ	Physica
ΠΖΜ	De Partibus Animalium
ΠΖΚ	De Motu Animalium
ΠΓΖ	De Generatione Animalium
Πψ	De *Anima*
Γφ	De Generatione et Corruptione

The following translations were quoted:
Clarendon Press, Oxford:
Met: W.D. Ross, 1928—Φ: Hardie and Gaye, ed. Ross, 1930—ΠΖΜ: W. Ogle, ed. Smith and Ross, 1912—ΠΖΚ: A.S. L. Farquharson, ed. Smith and Ross, 1912—ΠΓΖ: A. Platt, ed. Smith and Ross, 1912—Meteorologica: E.W. Webster, ed. Ross, 1923 — Γφ: H.H. Joachim, ed. Ross 1930
Πψ: H. Lawson-Tancred, Penguin, 1986

[1] ΦΙΙ8, 199a, 8–11

Ἔτι ἐν ὅσοις τέλος ἐστί τι, τούτου ἕνεκα πράττεται τὸ πρότερον καὶ τὸ ἐφεξῆς. Οὐκοῦν ὡς πράττεται, οὕτω πέφυκε, καὶ ὡς πέφυκεν, οὕτω πράττεται ἕκαστον, ἂν μή τι ἐμποδίζῃ.

Further, where a series has a completion, all the preceding steps are for the sake of that. Now surely as in intelligent action, so in nature; and as in nature, so it is in each action, if nothing interferes.

[2] Met Z 13, 1039a, 6–7

οἷον ἡ διπλασία ἐκ δύο ἡμίσεων δυνάμει γε· ἡ γὰρ ἐντελέχεια χωρίζει.

[...] e.g. the double line consists of two halves—potentially; for the complete realization of the halves divides them from one another.

[3] ΠΖΜ 646b, 11–14, 19–28 and 30–37, 647a, 1–3

Ἐξ ἀμφοτέρων μὲν οὖν τὰ ζῷα συνέστηκε τῶν μορίων τούτων, ἀλλὰ τὰ ὁμοιομερῆ τῶν ἀνομοιομερῶν ἕνεκέν ἐστιν· ἐκείνων γὰρ ἔργα καὶ πράξεις εἰσίν [...] Τὰ μὲν οὖν ὁμοιομερῆ κατὰ μέρος διείληφε τὰς δυνάμεις τὰς τοιαύτας (τὸ μὲν γὰρ αὐτῶν ἐστι μαλακὸν τὸ δὲ σκληρόν, καὶ τὸ μὲν ὑγρὸν τὸ δὲ ξηρόν, καὶ τὸ μὲν γλίσχρον τὸ δὲ κραῦρον), τὰ δ' ἀνομοιομερῆ κατὰ πολλὰς καὶ συγκειμένας ἀλλήλαις· ἑτέρα γὰρ πρὸς τὸ πιέσαι τῇ χειρὶ χρήσιμος δύναμις καὶ πρὸς τὸ λαβεῖν. [...] Τὰ μὲν γὰρ ἀνομοιομερῆ ἐκ τῶν ὁμοιομερῶν ἐνδέχεται συνεστάναι, καὶ ἐκ πλειόνων καί ἑνός, οἷον ἕνια τῶν σπλάγχνων· πολύμορφα γὰρ τοῖς σχήμασιν, ἐξ ὁμοιομεροῦς ὄντα σώματος ὡς εἰπεῖν ἁπλῶς. Τὰ δ' ὁμοιομερῆ ἐκ τούτων ἀδύνατον· τὸ γὰρ ὁμοιομερὲς πόλλ' ἂν εἴη ἀνομοιομερῆ. Διὰ μὲν οὖν ταύτας τὰς αἰτίας τὰ μὲν ἁπλᾶ καὶ ὁμοιομερῆ, τὰ δὲ σύνθετα καὶ ἀνομοιομερῆ τῶν μορίων ἐν τοῖς ζῴοις ἐστίν.

Animals then are composed of homogeneous parts, and are also composed of heterogeneous parts. The former, however, exist for the sake of the latter. For the active functions and operations of the body are carried on by these... Such properties, then, are distributed separately to the different homogeneous parts, one being soft another hard, one fluid another solid, one viscous another brittle; whereas each of the heterogeneous parts presents a combination of multifarious properties. For the hand, to take an example, requires one property to enable it to effect pressure, and another and different property for simple prehension. For this reason the active or executive parts of the body are compounded out of bones, sinews, flesh, and the like, but not these latter out of the former. [...]

For heterogeneous parts can be made up out of homogeneous parts, either from a plurality of them, or from a single one, as is the case with some of the viscera which, varying in configuration, are yet, to speak broadly, formed from a single homogeneous substance; but that homogeneous substances should be formed out of a combination of heterogeneous parts is clearly an impossibility.

[4] ΠΖΜ 647b, 18–21

Καὶ γὰρ τῶν ὁμοιομερῶν ἡ διαίρεσις ἔχει διαφοράν· ἔστι γὰρ ὡς ἐνίων τὸ μέρος ὁμώνυμον τῷ ὅλῳ, ἔστι δ' ὡς οὐχ ὁμώνυμον, οἷον φλεβὸς φλέψ (...)

[...] a sub-division that may be made in the class of homogeneous parts. For in some of them the whole and a portion of the whole in one sense are designated by the same term—as, for example, is the case with blood-vessel and bit of blood-vessel—while in another sense they are not; but a portion of a heterogeneous part, such as face, in no sense has the same designation as the whole.

[5] Meteorologica IV 12, 390a, 12–20

Οὕτω τοίνυν καὶ σάρξ· ἀλλὰ τὸ ἔργον αὐτῆς ἧττον δῆλον ἢ τὸ τῆς γλώττης. Ὁμοίως δὲ καὶ πῦρ· ἀλλ' ἔτι ἧττον ἴσως δῆλον φυσικῶς ἢ τὸ τῆς σαρκὸς ἔργον· Ὁμοίως δὲ καὶ τὰ ἐν τοῖς φυτοῖς καὶ τὰ ἄψυχα, οἷον χαλκὸς καὶ ἄργυρος· πάντα γὰρ δυνάμει τινί ἐστιν ἢ τοῦ ποιεῖν ἢ τοῦ πάσχειν, ὥσπερ σὰρξ καὶ νεῦρον· ἀλλ' οἱ λόγοι αὐτῶν οὐκ ἀκριβεῖς .

The same, then is true of flesh, except that its function is less clear than that of the tongue. So, too, with fire; but its function is perhaps even harder to specify by physical inquiry than that of flesh. The parts of plants, and inanimate bodies like copper and silver, are in the same case. They are all what they are in virtue of a certain power of action or passion—just like flesh and sinew. But we cannot state their form accurately, and so it is not easy to tell when they are really there and when they are not...

[6] ΦΙΙ 9, 200b, 5–8

Ἴσως δὲ καὶ ἐν τῷ λόγῳ ἐστὶ τὸ ἀναγκαῖον. Ὁρισαμένῳ γὰρ τὸ ἔργον τοῦ πρίειν ὅτι διαίρεσις τοιαδί· αὕτη δ' οὐκ ἔσται, εἰ μὴ ἔξει ὀδόντας τοιουσδί· οὗτοι δ' οὔ, εἰ μὴ σιδηροῦς. Ἔστι γὰρ καὶ ἐν τῷ λόγῳ ἕνια μόρια ὡς ὕλη τοῦ λόγου.

Perhaps the necessary is present also in the definition. For if one defines the object of sawing as being a certain kind of dividing, then this cannot

come about unless the saw has teeth of a certain kind; and these cannot be unless it is of iron. For in the definition too there are some parts that are, as it were, its matter.

[7] ΠΖΚ 702a, 27–33

Κινεῖται μὲν οὖν καὶ οὐ κινεῖ τὸ ἔσχατον τοῦ βραχίονος, τῆς δ' ἐν τῷ ὠλεκράνῳ κάμψεως τὸ μὲν κινεῖται τὸ ἐν αὐτῷ τῷ ὅλῳ κινουμένῳ, ἀνάγκη δ' εἶναί τι καὶ ἀκίνητον, ὃ δή φαμεν δυνάμει μὲν ἓν εἶναι σημεῖον, ἐνεργείᾳ δὲ γίνεσθαι δύο· ὥστ' εἰ τὸ ζῷον ἦν βραχίων, ἐνταῦθ' ἄν που ἦν ἡ ἀρχὴ τῆς ψυχῆς ἡ κινοῦσα.

Accordingly, in the case of the elbow-joint, the last point of the forearm is moved but does not move anything, while, in the flexion, one point of the elbow, which lies in the whole forearm that is being moved, is moved, but there must also be a point that is unmoved, and *this* is our meaning when we speak of a *point* that is in potency one, but which becomes two in actual exercise. Now if the arm were the living animal, somewhere in its elbow-joint would be situate the original seat of the moving soul.

[8] ΦΙΙ 2, 202a, 9

Εἶδος δὲ ἀεὶ οἴσεταί τι τὸ κινοῦν, [...]

The mover or agent will always be the vehicle of a form.

[9] ΦΙΙ 2, 194a, 27–30

Ἡ δὲ φύσις τέλος καὶ οὗ ἕνεκα· ὧν γὰρ συνεχοῦς τῆς κινήσεως οὔσης ἔστι τι τέλος τῆς κινήσεως [...].

For if a thing undergoes a continuous change and there is a stage which is last, this stage is the end or 'that for sake of which'.

[10] Πψ II 418a, 4–6

Τὸ δ' αἰσθητικὸν δυνάμει ἐστὶν οἷον τὸ αἰσθητὸν ἤδη ἐντελεχείᾳ, καθάπερ εἴρηται. Πάσχει μὲν οὖν οὐχ ὅμοιον ὄν, πεπονθὸς δ' ὡμοίωται καὶ ἔστιν οἷον ἐκεῖνο.

As we have said, what has the power of sensation is potentially like what the perceived object is actually; that is, while at the beginning of the process of its being acted upon the two interacting factors are dissimilar, at the end the one acted upon is assimilated to the other and is identical in quality with it.

[11] ΦIV 13, 222b, 12–14

Τὸ δὲ νῦν [...] ἔστι γὰρ τοῦ μὲν ἀρχή, τοῦ δὲ τελευτή. Ἀλλὰ τοῦτ' οὐχ ὥσπερ ἐπὶ τῆς στιγμῆς μενούσης φανερόν. Διαιρεῖ δὲ δυνάμει.

The 'now' is the link of time, as has been said (for it connects past and future time), and it is a limit of time (for it is the beginning of the one and the end of the other). But this is not obvious as with the point, which is fixed. It divides potentially.

(Note that, as his fellow-academic Henri Bergson was to do, Aristotle refuses to spatialize time).

[12] ΦIII 3, 202a, 11–14

Οὔτ' ἀνάγκη τὸν διδάσκοντα μανθάνειν, οὐδ' εἰ τὸ ποιεῖν καὶ πάσχειν τὸ αὐτό ἐστι, μὴ μέντοι ὡς τὸν λόγον εἶναι ἕνα τὸν τὸ τί ἦν εἶναι λέγοντα, ὡς λώπιον καὶ ἱμάτιον, ἀλλ' ὡς ἡ ὁδὸς ἡ Θήβηθεν Ἀθήναζε καὶ ἡ Ἀθήνηθεν εἰς Θήβας [...].

Nor is it necessary that the teacher should learn, even if to act and be acted on are one and the same, provided they are not the same in *definition* (as 'raiment' and 'dress'), but are the same merely in the sense in which the road from Thebes to Athens and the road from Athens to Thebes are the same.

[13] ΦVIII, 5, 257b, 8–9

Ἔστι δ' ἡ κίνησις ἐντελέχεια κινητοῦ ἀτελής. Τὸ δὲ κινοῦν ἤδη ἐνεργείᾳ ἐστίν·

[...] motion is an incomplete actuality of the movable. The movent on the other hand is already in activity.

[14] Γφ 323b, 29–34

Ἀλλ' ἐπεὶ οὐ τὸ τυχὸν πέφυκε πάσχειν καὶ ποιεῖν, ἀλλ' ὅσα ἢ ἐναντία ἐστὶν ἢ ἐναντίωσιν ἔχει, ἀνάγκη καὶ τὸ ποιοῦν καὶ τὸ πάσχον τῷ γένει μὲν ὅμοιον εἶναι καὶ ταὐτό, τῷ δ' εἴδει ἀνόμοιον καὶ ἐναντίον·

But since only those things which either involve a 'contrariety' or are 'contraries'—and not any things selected at random—are such as to suffer action and to act, agent and patient must be 'like' (i.e. identical) in kind and yet 'unlike' (i.e. contrary) in species.

[15] Πψ II 5, 417b, 13–16

[...] τὸ δ' ἐκ δυνάμει ὄντος μανθάνον καὶ λαμβάνον ἐπιστήμην ὑπὸ τοῦ ἐντελεχείᾳ ὄντος καὶ διδασκαλικοῦ ἤτοι οὐδὲ πάσχειν φατέον, ὥσπερ εἴρηται, ἢ δύο τρόπους εἶναι ἀλλοιώσεως, τήν τε ἐπὶ τὰς στερητικὰς διαθέσεις μεταβολὴν καὶ τὴν ἐπὶ τὰς ἕξεις καὶ τὴν φύσιν·

[...] we should say either that that which from a condition of potentiality learns and takes knowledge from what is in actuality and teaches is not affected at all, as we said, or that there are two ways of changing state, the change to privative dispositions and the change to natural states.

[16] ΠΓZ 734a, 17–21

Τὰ οὖν ἄλλα πῶς ; Ἢ γάρ τοι ἅμα πάντα γίνεται τὰ μόρια, οἷον καρδία, πλεύμων, ἦπαρ, ὀφθαλμὸς καὶ τῶν ἄλλων ἕκαστον, ἢ ἐφεξῆς, ὥσπερ ἐν τοῖς καλουμένοις Ὀρφέως ἔπεσιν· ἐκεῖ γὰρ ὁμοίως φησὶ γίνεσθαι τὸ ζῷον τῇ τοῦ διατόνου πλοκῇ· Ὅτι μὲν οὖν οὐχ ἅμα, καὶ τῇ αἰσθήσει ἐστὶ φανερόν·

How, then, does it make the other parts? Either all the parts, as heart, lung, liver, eye, and all the rest, come into being together or in succession, as is said in the verse ascribed to Orpheus, for there he says that an animal comes into being in the same way as the knitting of a net. That the former is not the fact is plain even to the senses...

[17] ΠΓΖ734b, 13–17

Ὥσπερ οὖν ἐν τοῖς αὐτομάτοις, τρόπον μέν τινα ἐκεῖνο κινεῖ οὐχ ἁπτόμενον νῦν οὐθενός, ἁψάμενον μέντοι· ὁμοίως δὲ καὶ ἀφ' οὗ τὸ σπέρμα ἢ τὸ ποιῆσαν τὸ σπέρμα, ἁψάμενον μέν τινος, οὐχ ἁπτόμενον δ' ἔτι· τρόπον δέ τινα ἡ ἐνοῦσα κίνησις, ὥσπερ ἡ οἰκοδόμησις τὴν οἰκίαν.

As, then, in these automatic machines the external force moves the parts in a certain sense (not by touching any part at the moment, but by having touched one previously), in like manner also that from which the semen comes, or in other words that which made the semen, sets up the movement in the embryo and makes the parts of it by having first touched something though not continuing to touch it. In a way it is the innate motion that does this, as the act of building builds the house.

[18] Πψ412b, 19–20

Εἰ γὰρ ἦν ὁ ὀφθαλμὸς ζῷον, ψυχὴ ἂν ἦν αὐτοῦ ἡ ὄψις.

If the eye was an animal, then sight would be its soul.

[19] Γφ324b, 13–15

Ἔστι δὲ τὸ ποιητικὸν αἴτιον ὡς ὅθεν ἡ ἀρχὴ τῆς κινήσεως. Τὸ δ' οὗ ἕνεκα οὐ ποιητικόν.

The active power is a 'cause' in the sense of that from which the process originates: but the end, for the sake of which it takes place, is not 'active'.

[20] Met M 1077a, 19–20, 25–31

τὸ γὰρ ἀτελὲς μέγεθος γενέσει μὲν πρότερόν ἐστι, τῇ οὐσίᾳ δ' ὕστερον, οἷον ἄψυχον ἐμψύχου [...] εἰ οὖν τὸ τῇ γενέσει ὕστερον τῇ οὐσίᾳ πρότερον, τὸ σῶμα πρότερον ἂν εἴη ἐπιπέδου καὶ μήκους· καὶ ταύτῃ καὶ τέλειον καὶ ὅλον μᾶλλον, ὅτι ἔμψυχον γίγνεται· γραμμὴ δὲ ἔμψυχος ἢ ἐπίπεδον πῶς ἂν εἴη ;

For the incomplete spatial magnitude is in order of generation prior, but in the order of substance posterior, as the lifeless is to the living [...] If, then, that which is posterior in the order of generation is prior in the order of substantiality, the solid will be prior to the plane and the line. And in *this* way also it is both more complete and more whole, because it can become animate. How, on the other hand, could a line or plane be animate?

[21] ΦΙΙ 207a,35–207b

[...] περιέχεται γὰρ ὡς ἡ ὕλη ἐντὸς καὶ τὸ ἄπειρον, περιέχει δὲ τὸ εἶδος·

[...] for the matter and the infinite are contained inside what contains them, while it is the form which contains.

[22] ΦΙΙ 207a, 26–28

[...] εἶδος γὰρ οὐκ ἔχει ἡ ὕλη. Ὥστε φανερὸν ὅτι μᾶλλον ἐν μορίου λόγῳ τὸ ἄπειρον ἢ ἐν ὅλου· μόριον γὰρ ἡ ὕλη τοῦ ὅλου ὥσπερ ὁ χαλκὸς τοῦ χαλκοῦ ἀνδριάντος [...].

[...] for the matter has no form. (Here it is plain that the infinite stands in the relation of part rather than of whole. For the matter is part of the whole, as the bronze is of the bronze statue.)

[23] ΦIII 207b,34– 208a

Ἐπεὶ δὲ τὰ αἴτια διῄρηται τετραχῶς, φανερὸν ὅτι ὡς ὕλη τὸ ἄπειρόν ἐστιν αἴτιον, καὶ ὅτι τὸ μὲν εἶναι αὐτῷ στέρησις, τὸ δὲ καθ' αὑτὸ ὑποκείμενον τὸ συνεχὲς καὶ αἰσθητόν·

In the four-fold scheme of causes, it is plain that the infinite is a cause in the sense of matter, and that its essence is privation, the subject as such being what is continuous and sensible.

[24] ΦVIII 261a, 13–14

Ὅλως δὲ φαίνεται τὸ γινόμενον ἀτελὲς καὶ ἐπ' ἀρχὴν ἰόν, ὥστε τὸ τῇ γενέσει ὕστερον τῇ φύσει πρότερον εἶναι·

[...] that which is in process of becoming appears universally as something imperfect and proceeding to a first principle: and so what is posterior in the order of becoming is prior in the order of nature.

[25] ΠZM 643a, 24

Ἔστι δ' ἡ διαφορὰ τὸ εἶδος ἐν τῇ ὕλῃ

A species is constituted by the combination of differentia and matter.

APPENDIX

A. Reading notes by Bruno Pinchard

Bruno Pinchard, *agrégé de philosophie*, was born in Le Havre in 1955, studied at the École Normale Supérieure in Paris and is now a research worker (*chargé de recherches*) with the CNRS (Centre National de la Recherche Scientifique). A specialist in sixteenth century Aristotelian philosophy, he came into contact with the work of René Thom through the intermediary of Jean Petitot and Pierre Lochak. Each of them in his way succeeded in convincing him that present-day metaphysics, though drawing inspiration from the history of philosophy, could not afford to shirk confrontation with modern science, and particularly with mathematics. From this clear evidence was born, in the course of a seminar at the EHESS (École des Haute Études Sociologiques), a singular collaboration with René Thom, during which, inch by inch, the reading of Aristotle, Averroes, St. Thomas Aquinas and Giordano Bruno threw new light on the morphological thesis presented in René Thom's mathematics.

These notes were set down after reading the text of a lecture given by René Thom at Maurice Loi's seminar on January 21st, 1987.

> *"Abstrahentium non est mendacium"*, Aristotle, ΦII, 193b, 35. It little affects the truth of the properly mathematical point of view, whether the mathematician should consider, or not, the objects of his science as an abstraction. Although it is true that these objects are not abstract in their being, yet do mathematicians not lie, in their purely mental abstractions: for they do not claim that these objects are outside sensible matter (that were to lie indeed), but they consider them otherwise than with respect to sensible matter, and this can be done without falsehood. In the same way, whiteness may

> be considered, in all truth, without reference to music, although both are to be found in the same subject. But that point of view would not be true if one were to affirm that the white man is not a musician.
>
> Thomas Aquinas, In Phys. II §161

Comments on Chapter 6

SECTION AII. "*Material*, and consequently spatial": this is a grave decision, for one might have expected: "material and consequently local". Space, for Aristotle, is but an object of thought, an *ens rationis*.

ulè noètè: I feel that you are confusing the entity of secondary substances (which is no more than an object of thought, of relationship, even if it does have a legitimate foundation in things) with the entity of mathematical objects which Aristotle does indeed characterize from an "intelligible matter". A mathematical object abstracts from movement and sensible matter, but not from continuous expanse, which is why it remains subject to the imagination. The universality of secondary substances, on the other hand, is purely intelligible, and these substances have no substrate other than the intentions of our intelligence (cf. Met 1036a, 9–12).

You might, if necessary, argue from *De Anima* 403a, 8 *et seq.* which suggests that all thought requires spatial representation. But echoing this text, 432a 10 explicitly distinguishes between spatializing representative functions (*fantasia*) and noetic enunciating functions (*fasis*).

SECTION AV. "Interaction": is it possible to think of this interaction in topological terms without taking into account the dynamics governing such contacts? For my part I imagine that Aristotle thought about contact from the starting point of motion rather than the other way round. That is, moreover, why he sought to prove the existence of the first mover starting from a consideration of continuity between mover and moved (ΦVII 2. 243a).

I come upon the same schema in those particular species of quality that are *shape* and *figure*. The figure does not in fact *finish* a determined quantity. A quantum can only be finished by a quantum because there can be a termination only *within the same genus*. We say then that figure and shape, in so far as they are qualities of quantity, *result* from the termination of quantity and only in this sense may they be considered as terms of quantity. Thus I see in the figure a real "centrality" of each quantitative termination and that is why it is the figure that renders sen-

sible the specific diversity of objects which is properly perceptible only through intellectual abstraction (Cat. 10a 10; ΦVII cap. III). Finally, when Aristotelians uphold the priority of quantity on quality, we must not understand the quantum, but rather that quality of quantity which shows specific differences (cf. Met Δ 14, 1019b, 33).

SECTION C. "Mental experience": I fail to see to what passage in Aristotle you are alluding when you propose your first definition of potentiality. For even in De Int. 23a, 7 (not to mention Met Δ 12), the possibility that accompanies an effectively realized act is not a mental possibility but a real power, present right into the realization of the act. It is this effective mixture of necessity, of actuality and of the possible that Kierkegaard (mistakenly I believe) criticized in Aristotle (*Riens philosophiques*, collection Idées, Gallimard, p. 317). As for your interpretation, it could perhaps be likened to that of Leibniz when he seeks to demonstrate the possibility of God before demonstrating His existence. However, for Leibniz too, possible entities, in order to be intelligible, are endowed with an ontological consistency of their own by the fact that they *tend* to exist. I believe that you are trying to apply to possibility in general what Aristotle says about the divisibility of the continuum which is indeed a mental possibility (although it always has correspondence in being. That is the meaning to my mind of Met 1039a, 5, confirmed by De Int 22b, 35; for if entelechy separates, then it shows that such a separation was indeed possible). Now Aristotle takes good care to distinguish this specific power, made of repetition and deprived of aim, from the dynamic potential which is your object here (ΦIII 206a, 18).

SECTION D. "Indispensable support": in what sense? Do you mean that there could be another principle than form to organize the substrate? Should we not rather speak of conditioning disposition? Otherwise any metaphysics of the form becomes impossible, your own schematisms contingent or simply empirical.

The "internal structure of matter": what Bacon called *schematismi materiae* (1). However I do not think that your quotation is decisive. All it does is reply to a problem of logic posed in the *Metaphysica* (Z 10 1035a and, for your problematics, especially 1.16 *et seq.*): should matter come into the definition of an object? Aristotle replies that in the concrete definition of natural beings, matter may be admitted. It is not, however, a question of the *individual* matter but of the matter which is *common* to the species. Now for my part I find that your structures, on the contrary, can only be approached from the point of view of the individuation of phenomena. This is at least the most reasonable standpoint

to which we are led by St. Thomas Aquinas' explanation of Aristotle's theses: cf. *De ente et essentia* cap. II and the theory of *materia signata*.

"Genetic legacy": why do you bring down to biological notions a phrase that raises the question of being and consequently of discursivity? Your expressions are sometimes difficult to grasp for the philosopher, because one never knows whether you are proposing a paradigm or whether you are attempting to *reduce* the concept to fit your model. Would you indeed accept that there is a risk of reductionism in concept modeling similar to the one you impute to the treatment of form by quantitative science?

"A secondary entity": there is however only one act for the mover and the moved. There is no transport of species as in the atomist's notion of perception. I can see that Aristotle's sentence is ambiguous. But it is possible to construct it otherwise (as was done in the Middle Ages) and to treat *oisetai* as a passive rather than a middle voice. It would signify something like "to be considered as". The sentence then means; "Form is always considered as that which moves".

Be that as it may, it does not seem to me to be a good thing to duplicate the act, for we then lose the specificity of the actualization and, as a result, the unity of the pregnance. I therefore suggest that it is better to speak of simultaneity through contact than of the transfer of actuality. That is why, when Aristotle evokes the possibility of the actualization of one entity being in another, he is describing a *continuous* passage whilst respecting the distinction between potentiality and actuality (Φ202b, 9). Moreover this is achieved in an admirable way by your model.

SECTION FI. "This means that building a theory of the *act*...": should we not finally establish a difference between verb and act, that is between discourse and being?

"The substance of which 'it is raining'...": I think this can be induced from Meteo 370b, 14. As for the figure of the rain, it appears to me to be considered in Meteo 347a, 10. Besides, one wonders whether Aristotle had to ask himself questions about the expression "It is raining". Does not the physicist have to choose, among the possible sentences describing the world, those which help to reveal principles and causes (Meteo 356b, 16)? In the expression "It is raining", the natural event is no longer a physical motion, but a simple grammatical inflexion: is not your problem *only* a logical one (the problem of paronymy)? In De Int 3, 16b, 11, I read, "Such expressions as 'is not-healthy', 'is not-ill', I do not describe as verbs; for though they carry the additional note of time, and always form a predicate, there is no specified name for this variety; but let them be called indefinite verbs, since they apply equally well to that

which exists and to that which does not... for they do not themselves indicate anything, but imply a copulation, of which we cannot form a conception apart from the things coupled" (translation E.M. Edghill, ed. Ross, 1928). It is true that the proper task of metaphysics is to inquire about this "not anything" in the verb and in general in being. It was however in favoring the being of this nothingness outside its function of composition (or cosignification, as they would have said in the Middle Ages) that Heidegger took the road towards thinking of an entity free of all form and of all substrate. That does not seem to be your aim.

"The substrate of the river" according to Φ212a, 19, is probably the totality of the river, and so its bed.

SECTION F2. "Interlinked" or "interlocked": at the time of the Renaissance there was a school which proposed a geometrization of predication. Their model was obviously not algebraic topology, but that part of rhetoric called *disposition* (between invention and elocution) and which was considered as an incitation to spatialize predicative relations and which we find again in the Characteristic of Leibniz: cf. W.J. Ong, *Ramus, Method, and the Decay of Dialogue (passim).* Could you not rather be seen, for your part, as introducing a new topic of *invention*?

"Collision": or contact? Is this not the whole difference between Aristotelians and mechanists?

SECTION F3. "Conflict": Aristotelians of the fifteenth and sixteenth centuries worked on this Empedoclean notion. For example, in order to conceptualize the cooling of water, they attempted to imagine the presence either of "intensive" substantial forms, or even of "virtual qualities" by which to explain the cooling down of water that had been heated. Thus Cajétan is able to write (a theory he considers only probable): "It may happen that the whole suffers, in a certain manner, an action on the part of the whole, as a result of the opposition of active qualities which are in perpetual conflict therein (*in continua pugna*)." Thomas de Vio-Cajétan, a great commentator of Aristotle and of Thomas Aquinas at the beginning of the sixteenth century (cf. note 9), *In Sum. Theol. in I*, 54a, 3; cf. Suarez who criticizes this thesis in the name of a more "irenic" and therefore quite dogmatic Aristotelianism: Disp. Met. XV, sect I, §9, p. 500–501.

"If... the act should fail...": it is precisely this eventuality that preserves the possibility of contingency, to which you quite rightly attach so much value. There is, in general, no consideration of movement that does not contain the notion of hindrance, weakening and corruption of substances (cf. Thomas Aquinas, *Contra Gentiles*, L. III cap. LXXII).

SECTION G. "Total availability": here you outline the whole theory of knowledge based on the capacity of the patient intellect to be anything at all.

"Cases": I believe that paronymy (or denomination) does not concern the act as such, but the signification of the act (through the imposition of names). Apart from that, why do you not speak of the temporality of verbs?

SECTION H. "Entity/actant": I suggest all the same that you should distinguish between the two, for one cannot put on the same plane the actualization of a substrate and the potentialities it may entertain with other substrates (potentialities always with respect to contraries; cf. ΦIII 201a, 34). We observe the same distinction between the essence of a soul and its potentialities. It is never heat, as such, that warms, but some warm substrate. So that we cannot as you say consider the act "in isolation".

"In a temporal sense": this purely structuralist analysis is one of the boldest aspects of your reading of Aristotle. I know very few commentators who would dare to tackle this kind of text. But you will understand if I feel obliged to resist the opposition you propose between an abstract morphological *telos* and the time experienced by subjects. It is true that your wish to go beyond the manifestation in time conforms well with the logic of Aristotle's thought. But in so doing you shift the accent from the substrates (and the metaphysics of their internal dynamics) to the interval separating them (which is but an object of thought for Aristotle). It is never possible to reduce the agent of an action to just the accident of the topological formula of actualization, as you propose to do. The whole of Aristotelianism can be summed up in this formula: there is no operation without a substrate. Consider these words of St. Thomas, words that take us well beyond a simple grammatical constraint: "Nothing can act by itself that does not subsist. To act is indeed to be *in actu;* thus one acts in the manner in which one is" (*Su. Theol.* I, 75, 2c.).

In short you present an extraordinarily precise schematism of the *conditions,* but you cannot show the deciding principle of the action (nor, moreover are you asked to do so, an abstention that enables one to say again, as in the text inscribed above, that you do not "lie"; there is no sin "by omission" in classical epistemology).

"Direction": it is not the time experienced by the subject that fills the pure form of the road, but the intrinsic qualities of the road itself. For Aristotle, as some author put it whose name I do not recall, there is a road connotation. This connotation lies in the fact that the connection established by a road includes the point of departure and the point of arrival as a component of the very form of the relation (and that is why

Aristotle refuses to accept that every relation should have a converse; cf. the fourth part of Vuillemin's book: *De la logique à la théologie*). Thomas comments as follows on the passage you analyze here: "Although we may say, when we consider the matter in an abstract way, that the space separating two objects is identical, if however we consider the terms of this space, as when we say that there is a distance from such a point to such another and from *this* last point to the first, then this space is neither unique nor identical" (§319). It is true that these points of view are virtual, but it is the dissymmetrical play of agent and patient which realizes them, and not the "injection of time experienced by the subject". It would be difficult to express this more clearly than Thomas: "Although there is but one movement, yet the categories involved in the movement are two, according as the predicamental denominations come from different frames of reference furnished by exterior things" (§323).

If we now consider that agent and patient are two distinct categories for Aristotle, we may hold that the proper role of catastrophe formalism lies in tending to *homogenize* two categories in an abstract formalism. Transformed into an ontological dogmatism, catastrophist thinking would signify no less than the destruction of the analogical structure of the being, in favor of a formal univocity where generic and analogical predications would be confounded.

However you may look at it, the fact that there is a *jump* between action and passion is part of the essence of Aristotelian thinking. This jump alone preserves the individuality of mover and moved. In short, in spite of the difficulties attached, the categorial discontinuity of beings is the only way of constituting substantial individual forms in the face of the variation differentials that prevail today, in philosophy at least (think of Deleuze) (2). It seems to me that you have entered this debate for essential reasons.

Luckily for you, my favorite saint added a remark that confirms the very liberal (and less inquisitorial than it may seem!) character of this way of thinking. In his opinion the essence of movement does not consist only of the ontological dynamism at work in things. Movement is also the result of a certain intellectual consideration. The *complete* movement has about it something of an *ens rationis*. If it were reduced to mere ontology, he says, movement would be no more than the passage of an imperfect act to its progressive realization. But movement is more than that: "For this imperfect thing to possess the intelligence of movement, we are required, also, to imagine it as a *medium* between the two terms" (§324).

To my mind you are doing the same thing and in this sense catastrophe theory *completes* a natural theory of movement which otherwise would be concerned only with the dialectics of perfection and imperfection. But should we consider this *medium* only in its structural properties? No, says Thomas; it is the *criterion which* makes it possible to distinguish between potency and act. In other words, your analysis is not only legitimate but necessary, so long as it does not diminish the effectiveness of act and potential in filling an empty space.

SECTION I. "Non-temporal basis": do you believe that what you are presenting in this way is the *truth* about ontological analysis? Are you not reductionist in your turn when you *reduce* dynamics to the opposition of time and a timeless structure?

"An unwanted accident": in the end, do you not find yourself being more animist than the Ancients themselves? One has the impression *that* you are *considering in the* same way a physical movement that occurs only in the line of the potentialities of objects, and the conflict of appetites in living beings, a conflict which is governed not only by physical laws but also by psychic ones.

"Topologically equivalent": you are formalizing a phenomenology of symmetries. But is this still valid for the dialectics of self-consciousness in the human order? (You are doubtless familiar with the objections raised by Lacan (3) or Lévinas (4) to the Hegelian dialectics of master and slave.)

SECTION J. "A long way from *continuous* progression...": and so a long way from Aristotle. Thus you pass from a philosophy of the act to a philosophy of force.

"Categorial description": we are still talking of those *famous* "antepredicaments", *that is*, conditions under which objects may be signified by words (and their flexions). I see here rather a theory of modes of signification, preparatory to categorial semantics.

SECTION K. "Housebuilding": this question of architecture seems decisive to me, insofar as I discern there a first approximation of catastrophe theory (in the plan, the cross-section, the model) and at the same time a first *criticism* of it (in the resistance of materials, work on the site, and finally the scrapping of the plan in the completion of the building).

In this line one might reproach you *with:*

1. Leaving out the specificity of production, the proper dimension of action (cf. in Eth. Nic. III 5, the compared analysis of investigation and deliberation; however it is true that 1112b, 20 would be *very* much in your favor).

2. Reducing the task of movement to the temporalization of a pure form. Yet it is on the subject of architecture that Aristotle achieves great precision in the presentation of his dynamics, when he "analyzes" the reality of the "buildable" as such and distinguishes it from the finished construction (Φ201a, 16, 201b, 9). Now the architecture is not only in the house that is built, but in the act of building itself. The "mover" in architecture is not only the "mental image of the project in the architect's mind". Particularly for the great theorists of Vitruvian humanist architecture, who tried hard not to reduce the origins of architecture to the "primitive hut" (unlike their successors of the seventeenth and eighteenth centuries), it is the architect's job to direct work on the site and to transform the plan according to the necessities of the climate and of the materials at his disposal. This amounts to drawing a distinction between the "idea" of the house and its form, its "programming" and the "carrying out" of the opus (5). In other words, the architect's final cause is not simple (the architect is not just a space technician: cf. Eth Nic. 1098a, 30) and it may be said that there is no classical architecture that does not carry in its realization the trace of the processes of its construction. Will your formalization be able to render these subtleties? Is there, in a work, a formalism for the architect's *prudence* (that is to say, finally, for the resistance and the working of the material moved by the builder's dynamism—cf. Eth. Nic. 1137b, 29)? I can imagine a very fine catastrophe where, *in the architect's judgment,* the actuality of the buildable as such would be articulated with the edified house, a catastrophe distinct from that which links the architect as mover and final cause to the house as the thing moved. If we are referring to Met HZ, 1043a, 14, I am asking you to pass from the point of view of the actual to the point of view of the composite.

Comments on Chapter 8

SECTION E. "The sublunar universe": it seems to me that Aristotle does not mean that only animate beings are capable of accidental movement, but that animate beings are so in virtue of their union with bodies where forced movements are in full play (in the course of transmutations).

"Exterior catastrophe": why can this not be expressed in terms of truth?

"Secrete": this has a meaning for us too (I find this analysis very interesting). The discursive formulation of knowledge does not "reflect" reality, but results (through projection onto the verbal chain) from the information of sensory images by the high point (O)* that constitutes the active Intellect. For us the "organizing center" of the act of knowing is the passive Intellect. Could one not say however that the slope towards the subject is proper to judgment, and the slope towards the object is the natural slope of dynamics?

"Says very little...": what do you make of the theory of pleasure in the *Ethica Nicomachea* (and the famous flower of the act)? (6)

Quotation [15]: I do not think this is the meaning of the text. Aristotle speaks of privation here only in order to signify the *positive* alteration that results from actuation (disposition). In any case, the forms of privation you describe do not seem to me to have a place in the Aristotelian theory of discourse. With him the reference is fixed by a different process. This is how, in the wake of Cajétan, I see the matter (*In Isagogen*, ed. Marega, p. 19–20).

All predication is in the first place a conjunction of things, subsequently reflected in a formal relation based on the verbal copula. Nouns signify relations of reason which are introduced among things by the intellect. These intentions have their *foundation* in things, inasmuch as things are subject to consideration by the intellect. The intention itself is a *relation* and the thing submitted to intention is *named* by this relation. The relation is *signified* (formal use of the noun), the subject named by the noun is *referred* (fundamental use of the noun). Logic, then, is the science of nouns inasmuch as they signify *and* refer by denomination. But it is only a descriptive science which is ignorant of its conditions of exercise. These are founded on the theory of the act recalled above (cf. "secrete").

"The theory of language": not only in language; it is the very process of knowing in that it is endowed with a *ratio collativa*. But you are right to wonder whether these "controls" have an imaginable objective structure short of motion and finality. However you are perhaps neglecting the function of knowledge of the cause which in fact separates technique from the empirical links of experience. The problem, moreover, is more complicated when related to the question of unity in a composite definition of substance and accident (Met HZ 1030b, 8). Observe that Aristotle seeks the answer to this question through analogy with the being, in the passage to which I refer (1.10). Is there an elementary catastrophe to formalize analogy? When you "bind together", I would remind you of

* "*le point haut* (O)": there is a pun here in the French that is not translatable... (translator's note)

the doctrine of the separation of categories; when you "separate", then I would ask you for *formalisms* of synthesis. I always act in the name of analogy (but perhaps you will not hear of an analogy of the being in Aristotle? That would be a pity since what we are trying to do here is to intensify Aristotelian rationality).

Comments on the Conclusion

SECTION A. "Criterion of individuation": are you talking about the individuation of the stone or of the movement imparted to the stone? Is there still any meaning in that? If the "world is made up of entities", what does the individuality of an event signify?

"Conditional": do you mean that for a final cause, unintelligible as such, you substitute the morphogenetic field that has the same function, but whose topological nature is less costly on the ontological plane?

"The quantitative dimension": and yet quality is based on quantity, which is in its turn subject to quality in form and figure. It is then up to quality to assume all interactions between objects (in the mode of alteration). Is there not, as you envisaged earlier when it was a question of action and passion, a morphogenetic field specific to the apportionment of quality and quantity whose basic domain would be constituted of qualitative alterations (cf. ΦVII cap.2 and 3)? Your theory would then be an obstacle in the way of the dialectic circularity described by Hegel as existing between these two categories in his Logic of Being (restoring a form of univocity) (7).

"Junction morphology": I most particularly admire this passage in your study, even though I suffer from your constant analogies between the theoretical and the practical orders. There is indeed nothing surprising about the fact that a practical act should *bind* (as for the Iliad *in* Met HZ 4). The theoretical is resolutive (getting down to principles), but the practical is compositive (it orders an action with respect to an end).

Whatever the reservations I have intended to express in these questions, I truly believe that, far from being an obstacle to the consideration of being, the mathematical schematization of forms makes it possible to restore some content to the high way of accession to being, the way that passes through *substance* (and the multiplicity of particular sensible substances). To ask an axiomatical science to verify that amongst all the senses of being "that which 'is' primarily is the 'what' which indicates the substance of the thing" (Met Z, 1028a, 13–16), is to have a science play the particular but exemplary role of a new *isagogè* in the metaphysical system, an introduction that is not *logical* like that of Porphyry, but

objective and *physical*. Here is something that will permit us to talk legitimately, as at the time of the Renaissance, of an *Aristoteles Redivivus*.

Indeed, whosoever adheres to Aristotle's thought will welcome *as real* progress in his philosophy the *fact that* an attempt has been made to add a theory of individuation of causal ties to the theory of substances. Philosophy has never been so close to taking up at new cost the question of substance as a subject, that is to say as a particular substance. Instead of engulfing the question of substrate in a logical enquiry constantly seeking the ultimate reason for all predication, modern morphological theory makes it possible to apprehend bodies under their singular appearances and in the singularity of the event that determined their contours. That an event should create at the same time both a form and a non-repeatable singularity of the form, this is an attainment that can no longer be neglected by those who strive to continue Aristotle's way of thinking.

Traditional Aristotelianism had already established close connections between forms and their spatial appearances, for example in the Thomist thesis of individuation in matter—a quite scandalous thesis that gave its full weight to physical eschatology. This extreme vanguard of reflection on the substrates of bodies could not fail, unfortunately, to be carried away by the paradox proper to the ontology of real relations: the *real* communication of action between substances is indeed marked there, but we find superimposed on it a thesis on the *logical* solitude of *essences* which contradicts the philosophy of event singularity that was expected.

The history of Metaphysics will certainly not be contained in this debate, but it takes an irreversible turning when examined from this particular point of view. We think of those substantial forms so inevitable that Leibniz was obliged to "rehabilitate" them before making sure of the philosophy that was to dismiss them forever with their semantico-morphological ambivalence.

We had to wait for Mathematics to be capable of taking up the challenge of forms before an attempt was made to update a philosophical possibility that modern critics of metaphysics could only sketch or retrocede to the marvellous realm of the irrational. Obviously this is not without consequence. The coming back of substantial forms has taken a sufficiently unexpected path to leave the metaphysician somewhat bewildered. Has the time really come for him to entrust to a kind of modelization of manifestations—perhaps contingent, perhaps reductionist—the tradition within which he has learned to re-order the system of the position of objects in the whole?

Rather than opt feverishly for one or the other of these alternatives, it would be wise now to multiply tests of detail. To what extent does the metaphysical tradition shelter suppressed morphologicism, to what ex-

tent not? How can the tradition of essence claim to rationalize, by itself alone, the system of pregnances and salient forms? What can we learn, in this sense, from the wildest speculations as to the presence of angels in the place, their *tactus virtutis*, when we oppose it to the *tactus quantitatis* proper to the world of compound substances (8)? Should even the ethical sphere remain unscathed by catastrophist enquiry? Can CT help us to think out the ambiguity there is in Aristotelianism between the end of the act and the end of the agent. What, for instance, is love? Is there a "morphology" for the similarity presupposed in Aristotelian tradition by the action of the lover on the passivity of the loved one (9)? What, indeed, is ecstasy, and can one come out of oneself without some specific morphology? There must be an inference when we remind ourselves that the whole development of Italian Renaissance humanism (from the *Dolce Stil Novo* onwards) (10) was based on the difficulties in scholastic theory surrounding human and divine love. Contemporary with the modern elaboration of the notion of space, this humanist tradition has continued the morphological project into our time, through the arts of discourse and image.

Yet we cannot lend such power to catastrophe theory without finally raising some question of a nature to disturb it. And who better than Aristotle can formulate an aporia for morphological thinking, particularly that current of thought which jealously arms itself against any definitive point of view regarding the whole or the unity of the world, a world which it prefers to invest according to whatever singularities may present themselves? Thus in Book II of the *Physica* we read this fine aporia concerning the whole and the part, which will serve as our epilogue: "There is, indeed, a difficulty about part and whole, ... namely, whether the part and the whole are one or more than one, and how they can be one or many, and, if they are more than one, in what sense they are more than one. (Similarly with the parts of wholes which are not continuous.) Further, if each of the two parts is indivisibly one with the whole, the difficulty arises that they will be indivisibly one with each other also" (11). Will the prejudice of radical plurality proper to CT withstand this ascendancy of the whole, whose irresistible propagation up to the re-establishment of an undifferentiated equilibrium is described here in Aristotle's dialectics? The return of Heraclitus, would it not also mean, in the self-same movement, the return of Parmenides? Would catastrophe theory then be obliged to distinguish eternal essences, "unalterable and unmodified", separated from the world, in order to restore order to the chaos of elementary forms (12)? Or would it succeed in showing that even in the order of absolute intellection, there is also still place for morphologies—*suprasensible* ones this time?

B. The Author's comments on Bruno Pinchard's reading notes

"ABSTRAHENTIUM NON EST MENDACIUM" and TEXT OF THOMAS AQUINAS. The man who, in play or by conviction, confers meaning on a linguistic expression that is usually considered to be without meaning, would no longer be called a "liar" today. Were it not so, poets, philosophers, and even mathematicians, could not escape the opprobrium of mendacity. These last, for example, had been using the (absurd) expression $\sqrt{-1}$ for two centuries before a plausible interpretation became available. "Philosophy" is largely a question of accepting (or rejecting) expressions formed from recognized formal mechanisms, in a surprising semantic context. In the best cases, it is practice (empiricism) which takes the decision; failing that, it is the philosopher's "prejudices". Underneath, of course, there remains the opposition between Plato and Aristotle. Much as I admire the latter, I am still a Platonist insofar as I believe in the separate ("autonomous") existence of mathematical entities, for we find ourselves there in an ontological region different from the "usual" material reality of the perceptible world. (The role of the continuum, or spatial expanse, is to ensure the transition between the two regions.)

MATERIAL, AND CONSEQUENTLY SPATIAL. The Greeks do not appear to have had a concept equivalent to that of the Cartesian expanse. The Platonic χώρα could have played the part; it is precisely a concept rejected by Aristotle, because he intends place to be a predicate of substance, instead of matter being a predicate of expanse. History and science have failed to settle the difference between Mach and Einstein: E. Mach favored a space generated by matter (and radiation). Einstein, in his old age, saw matter as a "disease" of space-time. My own reading of Aristotle is evidently Einsteinian, not Machist, and in this it is fundamentally "unfaithful" to the author.

As for ὕλη νοητή and the "space of a genus", you are right in the strict Aristotelian spirit. However one finds a number of metaphorical uses of ὕλη in Aristotle; see on the subject Tricot's note in Met Z 7, 1033a, 5 (note 2, p. 384 in the French translation). I also draw your attention to: τὸ εἶδος ἐκ τῆς τοῦ εἴδους ὕλης, Met Δ 24, 1023b,1, γένος ὡς ὕλη, Met Δ 29, 1024b, 8.

All I find in your quotation from *De Anima* 403a, 8, is the necessity of relating mental qualities to a living body. Other more significative passages can be found. For example ΦVIII, 7 is devoted entirely to showing that the *phora* is ontologically anterior to any other type of movement (μεταξολή). Finally there is the quotation given in Robin's *Aristote*, at the bottom of page 204: *De Memoria* (1450a, 7–9): "Pour quelle raison

n'est-il pas possible de rien penser d'une pensée pure et sans le continu et aussi de penser sans le temps des réalités qui ne sont pas dans le temps? C'est une autre question (ἄλλος λόγος)"*. Unfortunately, adds Robin, one searches in vain for the place where this other question is dealt with in the extant works of Aristotle.

It seems to me that in the heart of Aristotelianism there lies a latent (and permanent) conflict between an Aristotle who is logician, rhetorician and even, when he criticizes Plato and the Ancients, sophist, and another Aristotle, who is intuitive, phenomenologist, and almost in spite of himself, topologist. It is with this second (rather misunderstood) Aristotle that I work, and I tend to forget the first (13). He hoped to make the junction with the help of the concept of *separation* (χωρίζειν), of fundamental importance in his *Metaphysica*. In Met Δ 1022a, 8, it is said that the "limit" is "the substance of each thing, and the essence of each; for this is the limit of knowledge; and if of knowledge, of the object also." (This is almost *esse est percipi*!) Is separation purely metaphorical? If it has an ontological bearing, then there must be an extended substrate, a continuum, against which things stand out. If not, then separation is but a *Gedankenexperiment*, on which we cannot hope to base objectivity.

INTERACTION. This is of course a modern notion. But one does find the lineaments of this concept in Aristotle. The patient *antikinei*, for instance versus the agent. Cf. also ΦIII, 1, 201a, 19–23, πολλὰ ἤδη ποιήσει καὶ πέισεται ὑπ ἀλλήλων (such things will act and be acted on by one another in many ways). The Newtonian principle of equality between action and reaction in mechanics surely has Aristotelian roots. In modern science, "contact" is not an important concept, for Physics does not consider "bodies" so much as *places* individuated by a repellent potential. So for us moderns, the requirement of contact for interaction between two entities is just a formulation (too strict, in its metaphysical demands) of local determinism. Moreover Aristotle does often speak of intermediaries (μεταξύ) through which take place actions and reactions between substances.

FIGURE AND SHAPE. I suppose we are talking of μορφή and εἶδος.

If you maintain the centrality of the figure (μορφή), then the notion of homoeomerous substance must be a problem for you, since, by definition, a homoeomerous substance has no boundaries properly speaking, and a figure is defined—at least partly—by its contour, its limits. That is

* "Why is it not possible to think anything in *pure* thought without the continuum, nor to think without time about realities which are outside time? That is another question."

why, as a mathematician, in order to define a homoeomerous part, I have to multiply the substrate space by an invisible space, an (interior) space of qualities—the space of a genus—so as to determine the *bounds* of my *homoeomerous quality. If this construction is not allowed there* subsists a hiatus between the logical and the morphological that cannot be bridged. For the *materia signata* that is the support of a homoeomerous quiddity has no visible detail to make a figure of it. The *forma substantialis* has no shape (in the ordinary sense of the word), and the *materia formalis* does not exhibit a formal character. Besides, the sentence, "A quantum can only be finished (limited?) by a quantum because there can be a termination *only within the same genus*" raises difficulties for the topologist that I am. What limits a volume is its surface, that is to say a two-dimensional being that is qualitatively (topologically) different from the three-dimensional "quantum". Aristotle was aware of this, for in ΦIV 13,222a, 12–15, he says that, for time, the instant, τὸ νῦν, is the beginning of one interval and the end of another. No doubt you will say that time is not a genus. True, but time operates, by motion, in every genus! Perhaps there is an ambiguity here between ἔσχατόν (limit or boundary) and περιεχόμενον (envelope).

MENTAL EXPERIENCE. The term is obviously an anachronism and we will find no such thing in Aristotle (except maybe what he says about φαντασία?). Reading you, I have the impression that for you the state of potency (τὸ δυνατόν) has a certain reality, a "real power, present right into the realization of the act". But I do not think I am mistaken in affirming that there are potential states of an entity that will never be realized. The whole theory of contingent futures points this way. The future of an entity that is effectively realized is never more than a minute part of the virtualities it contains *in posse*. And I do not see how one could define the virtualities held by an entity *in posse* without recourse to mental experience. True, "potency" has a certain ontological bearing: there is some agreement between the outside world and the way we represent it to ourselves, and consequently a transformation of being that we conceive to be possible may—if certain external conditions are fulfilled—be realized. But the mind will always imagine more than reality will produce, since we can, in imagination, recall the past and anticipate the future. Whence the role of time in phenomenal change. The aim of physics (in Aristotle's sense as well as our modern one) is to formulate *rules which*, at the best, determine univocally what is real from amongst what is possible—or, in a lesser way, describe constraints that have to be satisfied by the real in order to emerge from the possible. I do not see how one can speak of an "effective" potency that would be part of the total virtual potency, since the effective potency would have to be simul-

taneous and coincide with the realization of the act. (Unless, of course, you are referring to the famous definition of movement, ΦIII, 201a, 10–11, 90: the actualization of the potential being as such. We would then be dealing with an "instantaneous potency" (we would say, a speed-vector), which is but a tiny part of the global virtual power of the being at that instant. Your reference (ΦIII 206a, 18) which treats of the infinite, introduces one of the most enigmatic passages of the entire *Physica*—perhaps we should discuss it further. In short, the imagination of the mathematician mentally dissecting an object does not seem to me to be ontologically different from my making the hypothesis that if it is fine tomorrow I will go for a walk—and that consequently I am now a potential walker, even though in actual fact I am resting in my armchair.

INDISPENSABLE SUPPORT. Here it is the "catastrophist" speaking. A shape is spatially defined by its "catastrophe set". If we take into account quality spaces, superadded as fibers (internal spaces), the shape is then fully determined by a "section σ in the internal spaces, discontinuous on the catastrophe set".

INDIVIDUAL MATTER AND MATTER COMMON TO THE SPECIES. I find it hard to conceive of a matter common to the species. If we are talking about a homoeomerous substance like copper or silver, there can be a οἱ κεῖα ὕλη associated with the concept involving form (ὕλη τοῦ λόγου of quotation [6]). But such matter will clearly be, in modern language, a *class of equivalence among types of matter.* So it will be an abstract entity (although not separate).

GENETIC LEGACY. The linguistic structure of τὸ τί ἦν εἶναι says clearly what it means; as a being is linked with the permanency of its substrate, some of the properties of this substrate (those which do not vary with time) will subsist as they are; more generally, others will evolve in time according to their own nature. Whence an effect of the being's past on its present (and future). If what Spinoza says is true, that every being tends to persevere in its being, then every material being linked with its substrate must have some legacy that makes it what it is (taking past influences into account). The biological sense (of heredity) is a little stronger, because in this case there is a morphological gap between the adult and its progeny—through the egg. (An egg looks nothing like a chicken!) Thus the biological sense (genetic legacy) is an extension of the general sense of quiddity, rather than a restriction.

A SECONDARY ENTITY. The question of the "transfer of qualities" in the agent-patient interaction is a very subtle one. You are right in n

way: it is true that it is not heat that warms a cold body but rather another warm body. But I am not wrong either, it seems to me, in supposing that the agent emits an "influence" (a "pregnance") that will invest the patient. In the space of a genus (we will suppose it exists), there is an attraction of the patient's place (its image by σ) towards the agent's place. In this space there is a *phora* of the patient (from cold, he becomes warm). Quotation [10] on the theory of perception of what is sensible by the *nous pathètikos* is quite clear about this. I still think that the translation of οἴσεται by a passive in quotation [8] is inexact. The affinity of the future for the middle voice is standard in Greek grammar (justified moreover by the saying, *is fecit cui prodest*). In anticipation of what you say with Thomas on the specifically existential character of the agent, his proper activity, I would be tempted to propose a new metaphor. Since the agent is the grammatical "subject", he will occupy a *lower* place in the space of the genus. He will create around himself a "gravitation" towards his own position which becomes the center of the "world". There will result a "natural" movement of the patient, the object, towards the place of the subject, ending with both places becoming identified (unless, of course, there is *anti-kinesis*). This is the *slope towards the subject* that you mention further on in the linguistic model of the *logos apophanticos*. It is perhaps not absurd to think that Aristotle may have had this model in mind, unifying the natural geocentric movement of sublunar bodies and the action of the mover. But this movement in the space of a genus will be given a spatial interpretation in our usual space (the common substrate). There will be emission of a pregnance (a μεταξύ) by the subject, making the invested object like himself (from the point of view of the quality considered). After all, Sadi Carnot, the creator of Thermodynamics (1820), believed that a "caloric fluid" flowed from the warm to the cold body (a cascade that could be exploited as with a mill, for thermal machines). And in a collision, the moving body imparts to the moved one a part of its kinetic momentum. Thus a qualitative *alloiosis* can always be interpreted as the spatial transfer of a pregnance propagating itself from subject to object. For other types of action, for example if the agent shoots the patient with a revolver and kills him, the pregnance interpretation still holds, whereas that of attraction within the genus would become delicate.

BUILDING A THEORY OF THE ACT AMOUNTS *DE FACTO* TO BUILDING A THEORY OF THE VERB. Here I take up, albeit reluctantly, the torch of Aristotle's "linguistic" critics (Trendelenburg, Benveniste, etc., with regard to the categories "deduced from Greek grammar"). If I do so (whilst fully aware of the "reductionist" character of the procedure), it is because one may feel there to be in Aristotle an

implicit (and to my mind justified) confidence in the ontological bearing of natural language.

The relatively fertile nature of *this* methodology is already to be seen in the discussion of the "zero-valent" sentences of the "It is raining" type. In fact it is the problem raised *in fine* of your notes that is at stake here. If the world is made up of entities, what does the individuality of an event signify? There are criteria for the individuation of processes, the connectedness of the spatio-temporal domain that is the seat of the process being one of the most obvious. But that supposes that we admit among our entities beings of an accidental, transient type, formed from a fluctuating and mobile substrate. Apart from works of art, Aristotle scarcely mentions inanimate beings (ἄψυχα). It is true, as you say, that the physicist must concentrate on the generic situations (ὡς ἐπὶ τὸ πολύ) that characterize *phusis*. But rain, although it is not a constant phenomenon, is nevertheless a frequent one, important to man in its beneficial or harmful consequences. The accident, insofar as it affects human interests, ceases to be an accident, and is raised to the dignity of linguistic "fact", support of the *logos apophanticos* (cf. the Aristotelian distinction between αὐτόματον ανδ τύχη). Aristotle himself, in *De Generatione et Corruptione*, offers a vision of the hydrological cycle that modern science would find little fault with, but it is about rain as a species of phenomena, not about such and such an individual rainfall. It remains, nonetheless, that one of the aims of modern (if not Aristotelian) science is to reduce the part of randomness and to extend that of determinism. Such an extension naturally leads us to consider "badly individuated" phenomena. Heraclitus' river provides another example of these types of entity defined by their location in space-time (for the river, they are the anhomoeomerous interfaces between earth and water and between water and air) taken altogether, but treated longitudinally as homoeomerous components (the Seine, at Châtillon-sur-Seine and at Rouen, is still the same Seine). As I see it, an individual process is the investment of a salient form by a pregnance: "It is raining" signifies the investment of the "speaker's *topos*" by the pregnance that is rain, water in drops from the sky.

You are right, I do not follow Heidegger in his considerations on "being", starting from grammatically incomplete or semantically unacceptable linguistic segments. On the contrary I believe that semantic acceptability (in spite of its apparently relative character with regard to the language considered) generally has an ontological bearing. "All analogy is true, insofar as it is semantically acceptable." That, I believe, is the principle of all metaphysical investigation.

"συμπλοκή". These historical details are very interesting, and I should like to know more about them.

COLLISION OR CONTACT. Collision is obviously a particular type of contact.

CONFLICT. If "the act should fail"; must we admit that Aristotle's negative sentences bear witness to a positive and concrete reality?

THE CASES. I have not seen *cases (ptoseis)* mentioned elsewhere in Aristotle's work; for him that must belong to the theory of analogy, of πρός τι.

ENTITY/ACTANT. "Actant" obviously has a modern definition coming from structural linguistics. An actant is not necessarily an Aristotelian οὐσία, for it may be a pregnance (a μεταξύ): it is unfortunate that there should be nothing very precise in Aristotle on the ontological status of such intermediaries as sound, light, and so on.

THERE IS NO OPERATION WITHOUT A SUBSTRATE. This is like saying, in modern dynamics, that there can be no dynamics without the choice of a representative point and an initial condition. True, but that does not stop the dynamic framework from existing as a *constraint on the virtual.* The representative point is the ingression of the real into the virtual, where it propagates according to the equation of motion.

THERE IS A JUMP BETWEEN ACTION AND PASSION: It is true that catastrophe formalism tends to homogenize agent and patient. The difference, finally, is in the *time arrow*—its irreversibility. Of course, catastrophe analysis is itself incomplete, since it merely "shifts the problem", substituting for an observable phenomenal dynamic another (unknown) dynamic in the control space where the intentionality of the actants will come into play. So I am ready to admit the essentially *preliminary* character of catastrophe theory formalism.

A PERHAPS UNWANTED ACCIDENT. I do not really see why, in the final analysis, there should be no possible identification between dynamic behavior in inanimate nature and intentional or psychic behavior of suitably defined entities. Cf. in this sense A.N. Whitehead's *Metaphysics.* Attraction and repulsion are concepts of this type, having both physical and psychic value.

HOUSE-BUILDING. These "subtleties" in the execution of an architectural project are interesting, but do not, I feel, affect the structure of the process, always moved by a mental image in the architect's mind.

PLATONIC IDEAS. The problem is that of the presence of the form in an embryo. In the beginning, Aristotle says (ΦIII 7, 261a, 13–14) that the egg is *ateles* and moves towards its principle (ἐπ' ἀρχήν ἰὸν). In this phase the egg has no form, as can be seen in the fact that it is a "homoeomerous" substance that may (often) be divided. The parts will produce as many embryos (smaller but complete). Then what statute can be given to this future form, inexistent for the time being? Shall we say that the egg has no form, but that it has a τὸ τί ἦν εἶναι whose nature it is to subsequently develop the adult form (unless prevented from doing so)? This shows how infinitely richer and more mysterious the concept of "quiddity" is than those of form and actuality. (Here again is your *forma substantialis, alias materia formalis.*) Modern science can accept quiddities only on condition they are geometrized, in the substrate space or in derived spaces (functional spaces). This is what my "attractor of the metabolism simulating adult dynamics" signifies.

QUOTATION [15]. The paradox is here; the (founding) act separates, whereas the expression of *logos apophanticos* is composite (except for zero-valent sentences). No doubt this is because the linguistic expression of a fact is a finalized act (transmission of information).

THE EXTERIOR CATASTROPHE dwells precisely on the quasi-physical aspect of the linguistic fact, which always carries, for the receiver of the message, an element of discontinuity and of instantaneousness (in order to express a discontinuity, it is necessary to express a difference, the height of the jump-gap).

You seem to be saying that Aristotle would not have admitted that a secondary entity, as a concept, (a "common" noun), might be said to be in a state of privation. Indeed I believe that what separates the common noun from the proper noun is the privation of individuation due to localization (abstraction by "diaeresis"). Why not allow that an (abstract) secondary entity aspires to full reality, and suffers from "amputation" to use Aristotle's own terminology? You may of course argue that this "privation" exists only in the psychism of the speaker who feels the need to make the contents of his message explicit. But the metaphor by which

this intentional situation of the speaker *is projected* into the grammatical function itself appears to me to be justified, just as, if one were speaking of instruments, one might say that a lock suffers when it has no key, or a car when it has no wheels.

CONDITIONAL FINALITY. This means that predications based on the existence of a *morphogenetic field* are never certain, for they can only be realized if *nothing hinders their realization*. At the best they will be realized ὡς ἐπὶ τὸ πολύ if we are dealing with a "natural" morphogenetic field, such as those we find in embryology. Here, then, we are leaving the sure domain of physical laws for that of a certain probability related to a contextual situation, not described *stricto sensu* by the field.

THE "QUANTITATIVE DIMENSION" is indeed perhaps not necessary for intelligibility (which contents itself with "quality"). It is however necessary if the action is to be efficient. For to act is always to act *hic et nunc*. Since modern science cares more for efficacity than for intelligibility, one can see why it does not bother much about conditional finality.

Conditional is equivalent to: finality expressed in a qualitative way by a form defined up to a topological equivalence.

Absolute is equivalent to: absolute finality expressed by a form which unfolds in a local map related to the global geometry of space-time.

Conditional is then *absolu modulo* a topological deformation of structure (deformation about which nothing can be said in general).

Once again, thank you!

NOTES AND REFERENCES

(1) See Pierre Magnard's "La qualité ou l'autre chemin", *Les Études philosophiques*, No.3, 1985, p. 337.

(2) In *Difference et répétition*, chapter IV, § 1–4 with reference to Lautman, Paris, PUF, 1968.

(3) In *Écrits*, Paris, Le Seuil, p. 202, 415, 809 seq.

(4) Sorbonne lectures 1976.

(5) These analyses are borrowed from Daniele Barbaro, sixteenth century commentator of Vitruvius, and the interpretation proposed by Pierre Caye in his work *Le savoir de Palladio, architecture, politique et métaphysique à Venise au XVIème siècle*, to appear.

(6) *Eth. Nic.* X, 4, 1174b, 30.

(7) In *measure* theory: cf. *Science de la Logique*, Book I, third section, chapter III, B, p. 351, Paris, Aubier. To which one might oppose this text of Cajétan: "Comme la qualité implique un mode de la substance et le mode une détermination de celle-ci, it faut que la qualité soit dite en autant de sens que la puissance de la substance est modifiée ou déterminée." *In Praed.*, Rome, Angelicum, 1934, p. 172.

(8) Thomas Aquinas, *Contra Gentiles*, II, cap. 56; Capréolus, *In II Sent.*, Dist. II, q.1, a.2 and 3; Cajétan, *In S. Th.*, IP, Q. 52, a. 1. Nos II and III. Here I quote St. Thomas and his commentators, not as witnesses of Aristotelian orthodoxy, but by way of showing the powers of renovation and structuration of the Aristotelian *corpus* in the course of history. In this sense, the present remarks appear to me, in spite of their evident heterodoxy, to belong by right to the tradition of a perpetuated "scholastic philosophy".

(9) Cf. Thomas Aquinas, *S. Th.*; I II P., Q. 26, A. 2; Q. 28, a. 3 and 5.

(10) Cf. *Vita Nova*, cap. XXV where Dante wonders whether love is a substance in its own right (and even a corporeal substance) or just an accident of the substance affected by it. In the same way, can one make a catastrophe of the last lines of the song of Purgatory XXXI in *The Divine Comedy*, or of Petrarch's line: "*piagna per allentar d'arco non sana*" [the slackening of the arc does not heal the wound], sonnet XC?

(11) 185b, 11–16, translation Hardy and Gaye, ed. Ross.

(12) According to the suggestion of *De Caelo* 279a, 18.

(13) Note by R. Thom: Since writing this text I have discovered Daniel W. Graham's *Aristotle's Two Systems* (Clarendon Press, Oxford, 1987), in which two Aristotelianisms, incompatible according to the author, are systematically exposed.

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RENÉ THOM

SEMIO PHYSICS:
A SKETCH

Aristotelian Physics and Catastrophe Theory

ABOUT THE BOOK:

Semio Physics is a treatise on the neglected discipline of natural philosophy. It is the study of significant forms and an attempt at building a general theory of intelligibility. René Thom's hypothesis is that only certain configurations of elements can really make sense and be used as a basis for construction of intelligible linguistic description. The study explores how we identify beings to which meaning and intelligible behavior can be attributed.

The book is divided into two sections. The first part includes Thom's identification of two types of objects necessary for this morphology: salient forms, stable beings which stand out from their background; and pregnances, invisible entities which emanate and are captured by salient forms, evoking changes in each. The second part builds on Aristotle's attempt to construct a world physics theory based not on numbers but on continuity. This theory partly realizes the notion of the continuous as a point of departure, without evoking the intrinsic generativity of numbers. The book concludes that the restoration of intelligibility to the world demands a metaphysical approach.

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René Thom, Professor at I.H.E.S., Bures-sur-Yvette since 1963, was born in Montbéliard, France on September 2, 1923. He studied at the Ecole Normale Supérieure in Paris from 1943–1946, and obtained his Ph.D. in Mathematical Sciences in 1951. After a year spent at a graduate college of Princeton University, he was Professor at the Faculty of Sciences of Strasbourg University from 1954–1963. In 1954 Professor Thom invented and developed the theory of cobordism in algebraic topology. This classification of manifolds used homotopy theory in a fundamental way and became a prime example of a general cohomology theory. For this work, Thom received the Field Medal in 1958. Later on at I.H.E.S., he originated, with E.C. Zeeman, the celebrated Catastrophe Theory. Thom is a member of the American Academy of Arts and Sciences, Académie des Sciences de Paris, Deutsche Akademie der Naturforscher Leopoldina (DRG), and the Academy of Sciences of Brazil.

0-201-50060-4/Hardbound/288 pp/1989

ADDISON-WESLEY PUBLISHING COMPANY
The Advanced Book Program
Redwood City, California • Menlo Park, California • Reading, Massachusetts • New York • Don Mills, Ontario • Wokingham, United Kingdom • Amsterdam • Bonn • Sydney • Singapore • Tokyo • Madrid • San Juan

ISBN 0-201-50060-4